



CMSAF AVHRR-based CDR of TOA radiative fluxes (CLARA-A3): results and validation

Tom Akkermans, Nicolas Clerbaux

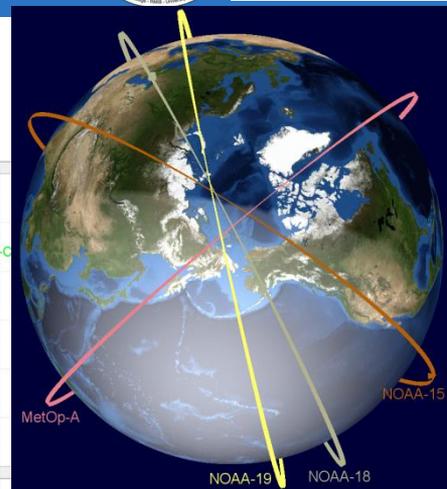
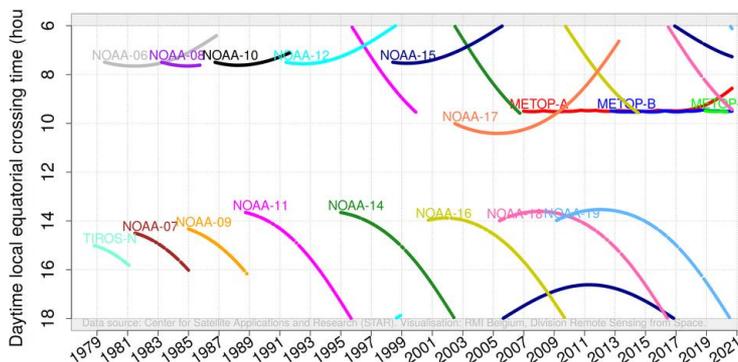
Fall 2022 CERES science team meeting

April 26-28, 2022

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• **What is CLARA?** “**CM SAF cL**oud, **A**lbedo and **RA**diation dataset from AVHRR data” (≈similar to Patmos-X):

- Polar orbiting : NOAA and MetOp
- FCDR from NOAA (Heidinger,2010)
- L3 products on $0.25^\circ \times 0.25^\circ$
- Currently released versions:
 - CLARA-A1 (1982-2009)
 - CLARA-A2 (1982-2015)

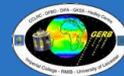


• **Some of the modifications in the upcoming version CLARA-A3:**

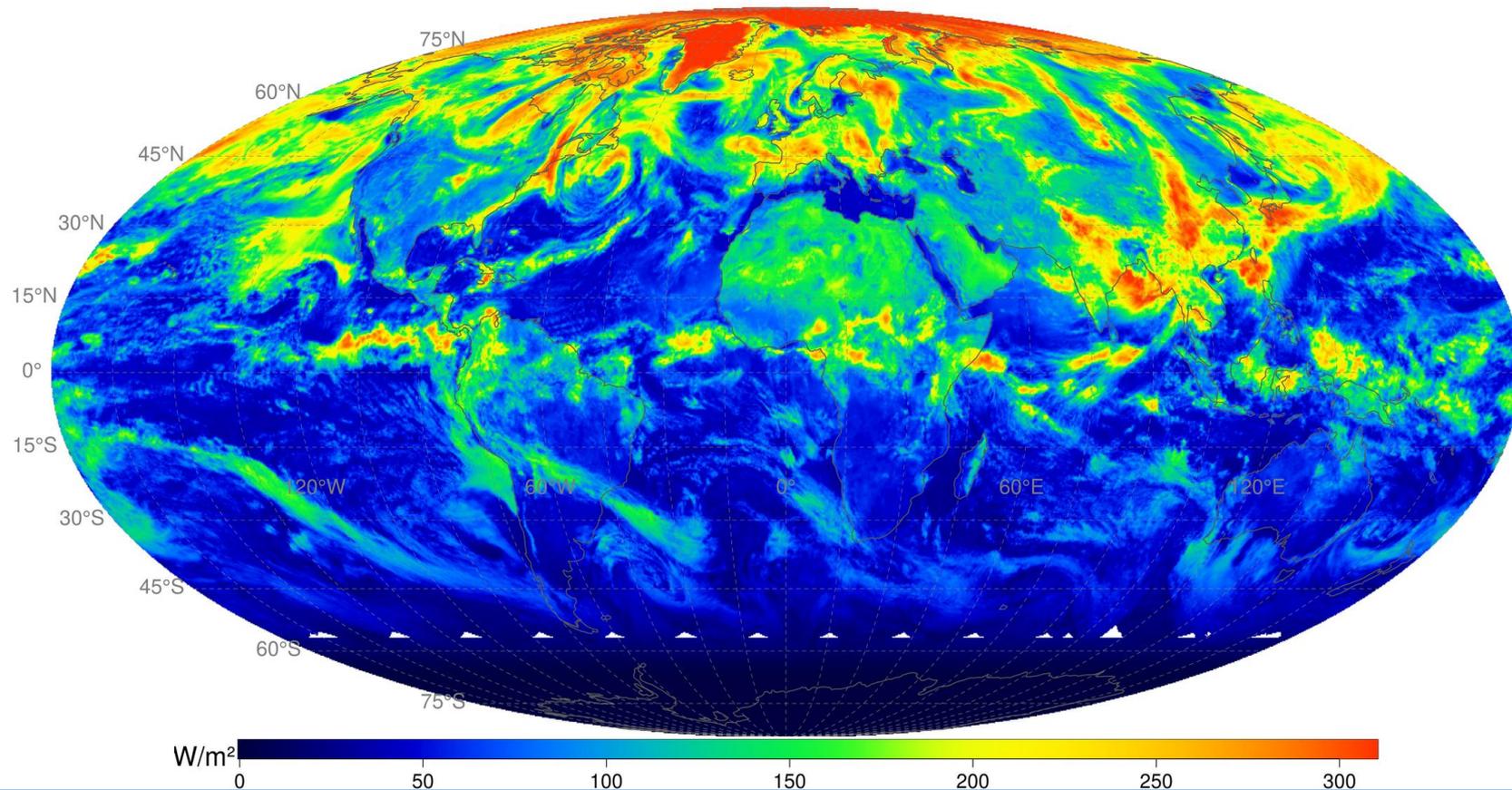
- Inclusion of the AVHRR-1 sensor (TIROS-N, NOAA-6,-8,-10): extension of time range to 1979-2020, which is 42 years
- Updated FCDR: new calibration for visible channels (latest PATMOS-x coefficients)
- Updated cloud treatment algorithms (NWC SAF / PPS v.2018; Karlsson et al.)
- **Addition of new product “TOA radiative fluxes” → this presentation**

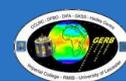


2. Results

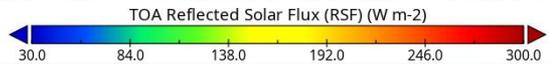
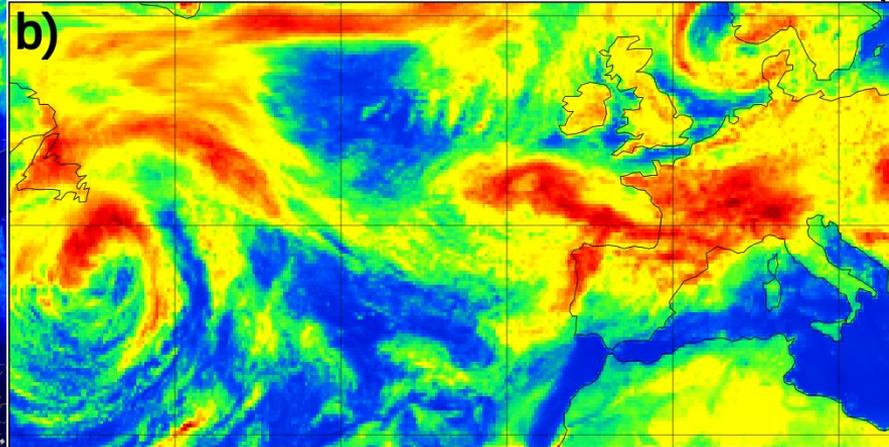
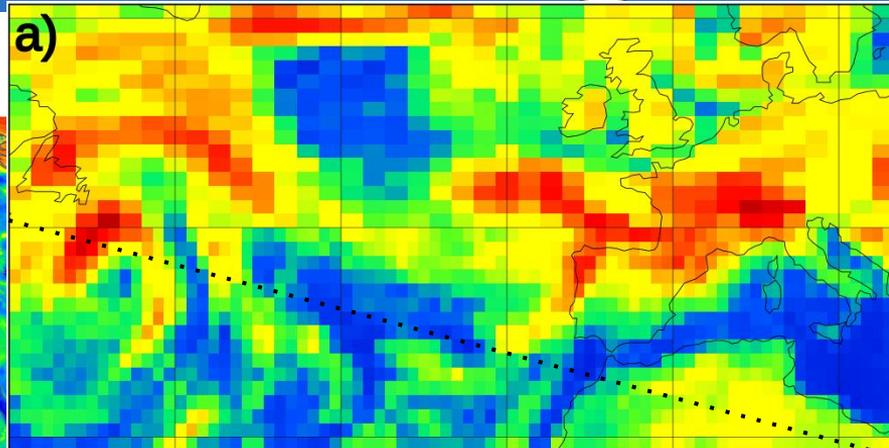
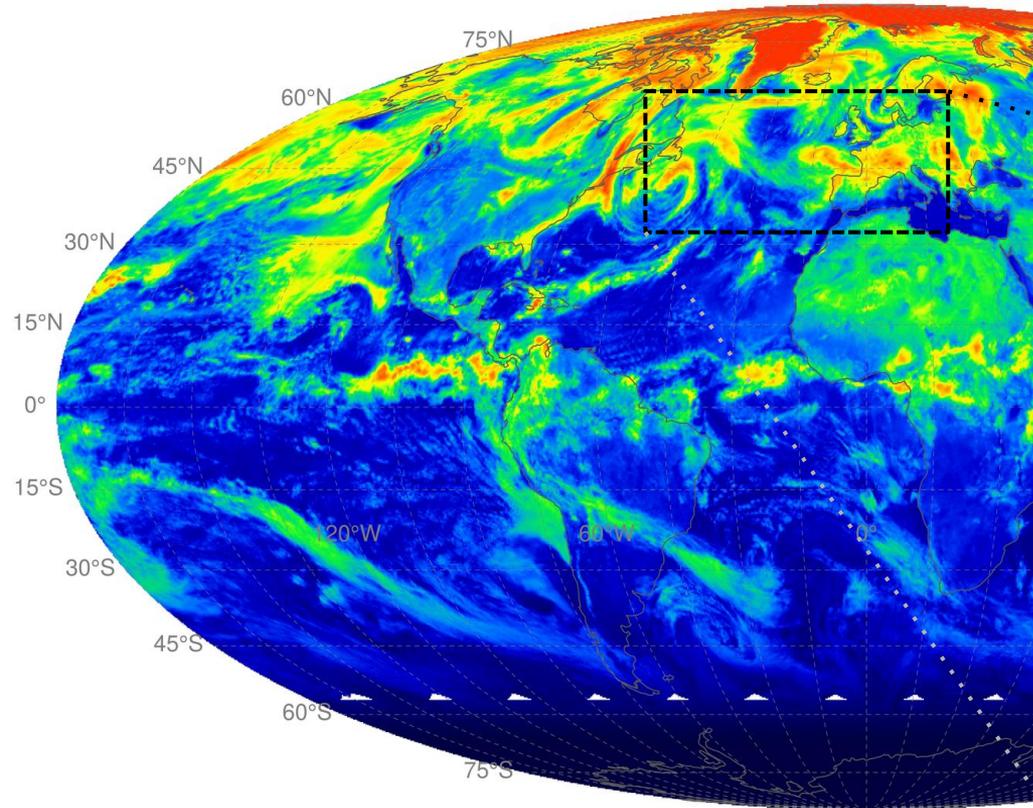


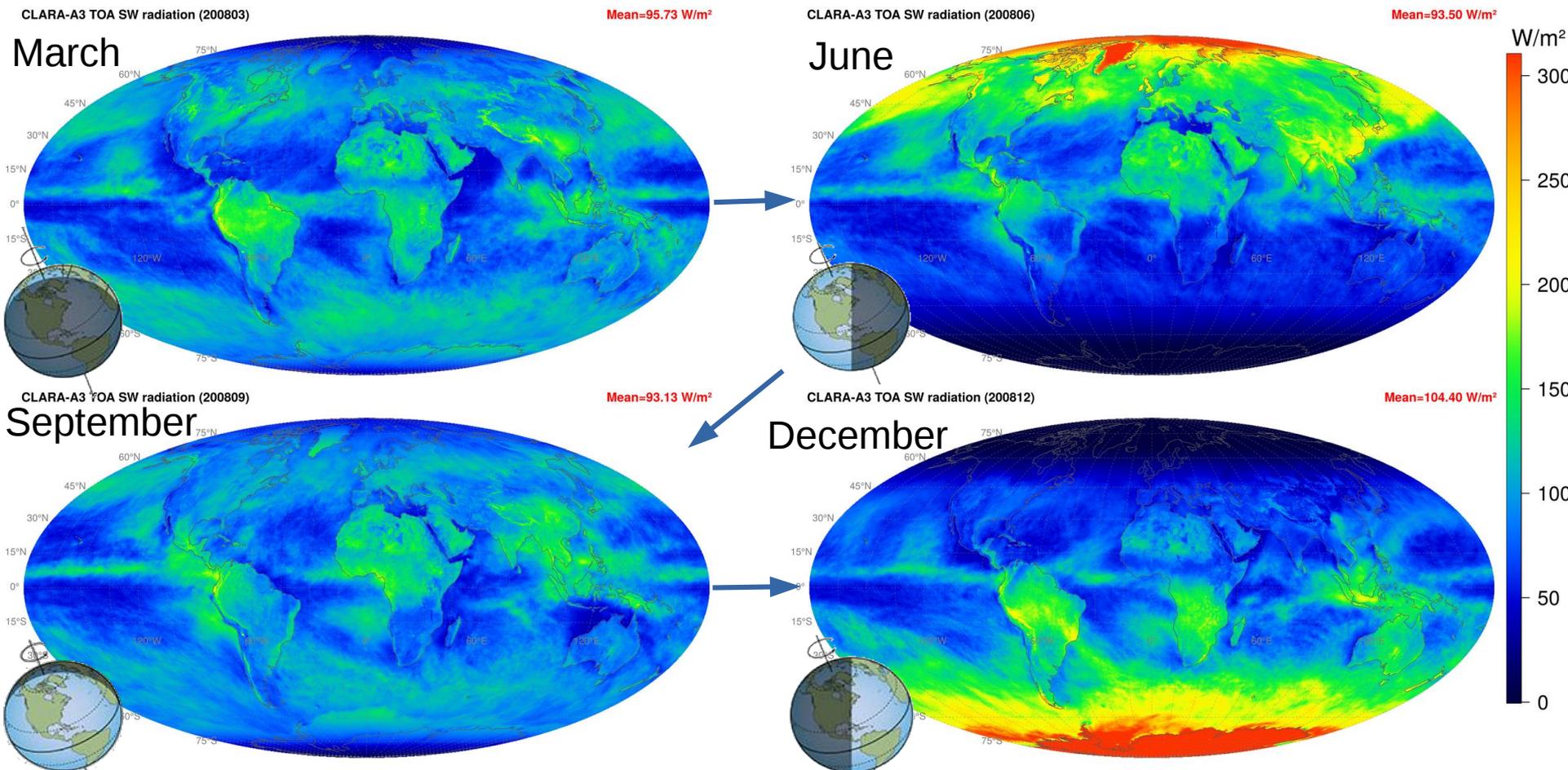
- Example: daily mean RSF (15/6/2008)



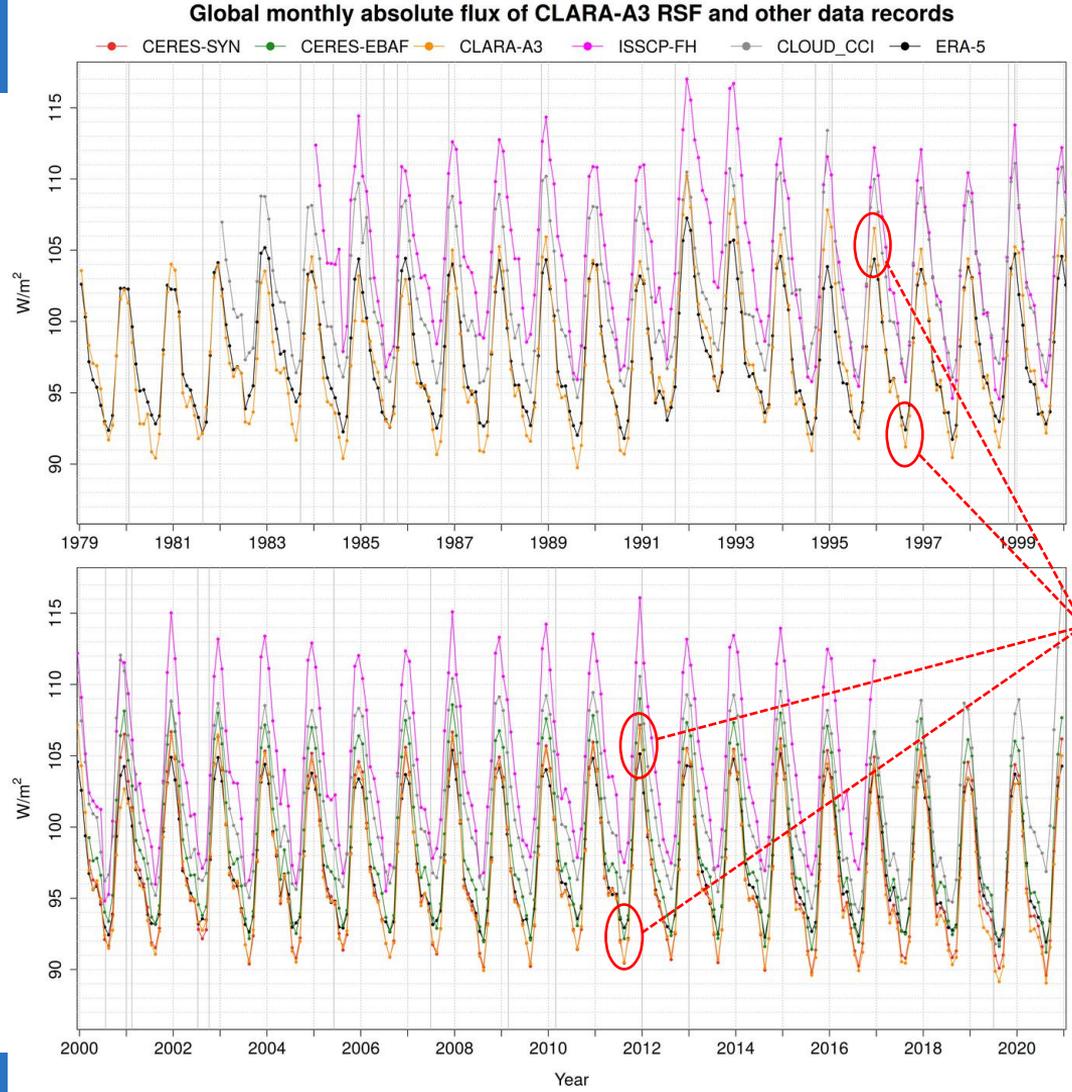


- Example: daily mean RSF (15/6/2008)





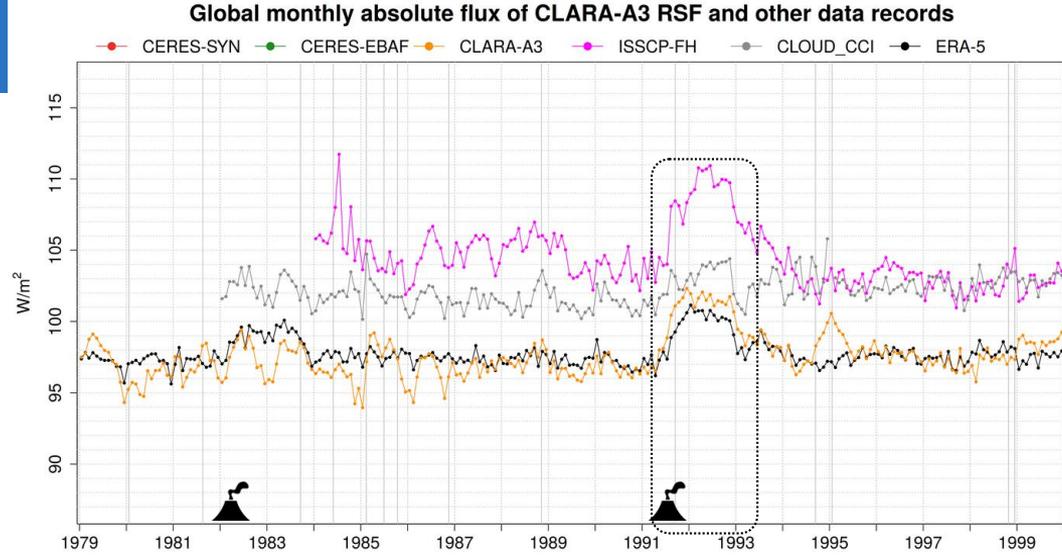
• **Global Monthly Mean RSF:**



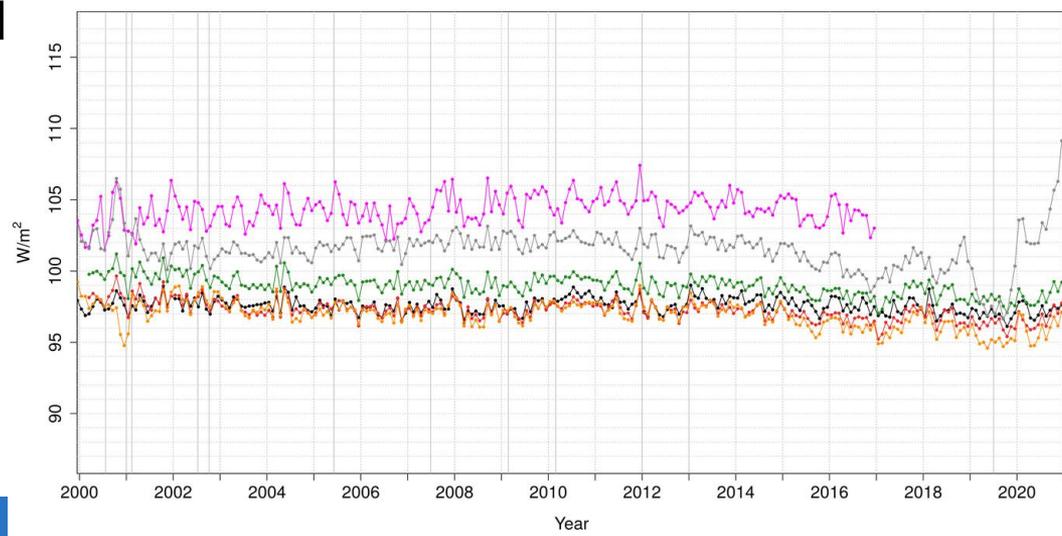
Systematic seasonal biases, e.g. from ERA5 w.r.t. CERES and CLARA-A3: underestimated amplitude of annual cycle

• Global Monthly Mean RSF:

• Deseasonalized



Major volcanic events



Trends (W/m²/dec):

Full series:

ERA5:	-0.0769
CLARA-A3:	-0.2318

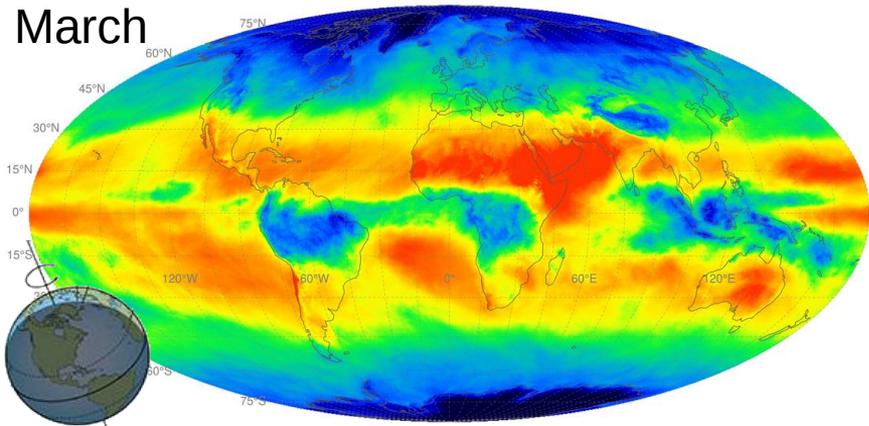
Since 2000:

ERA5:	-0.2024
CLARA-A3:	-0.9645
CERESSYN:	-0.6451
CERESEBAF:	-0.7023

CLARA-A3 TOA LW radiation (200803)

Mean=235.89 W/m²

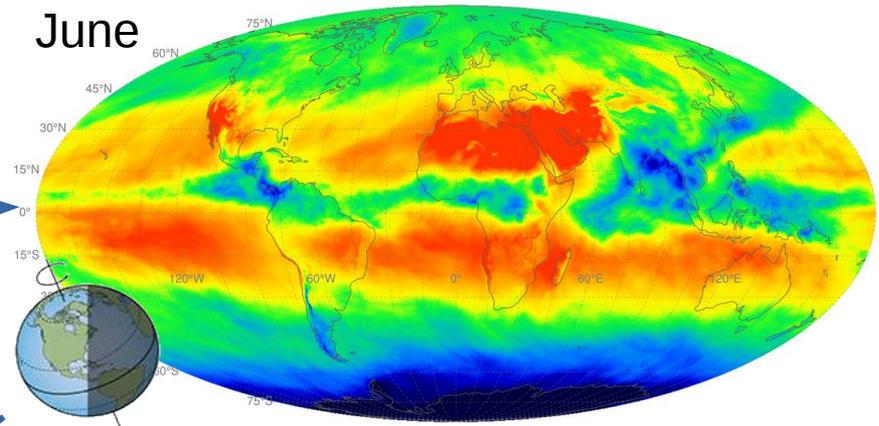
March



CLARA-A3 TOA LW radiation (200806)

Mean=240.39 W/m²

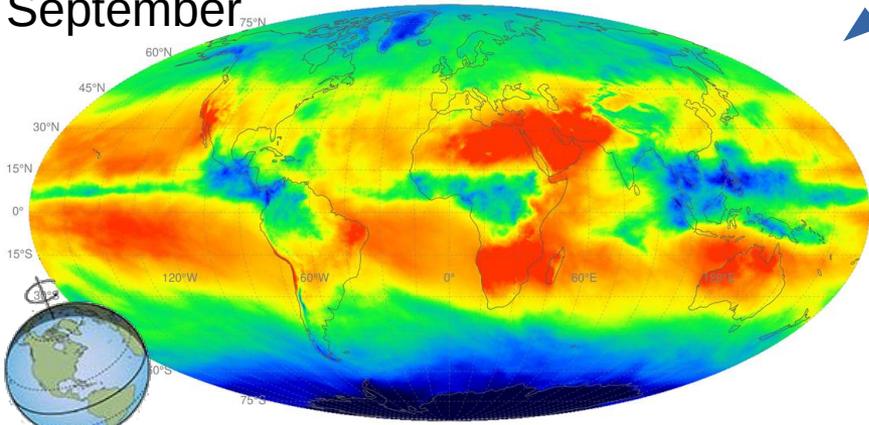
June



CLARA-A3 TOA LW radiation (200809)

Mean=240.03 W/m²

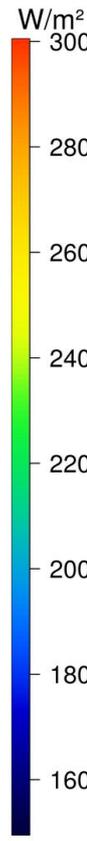
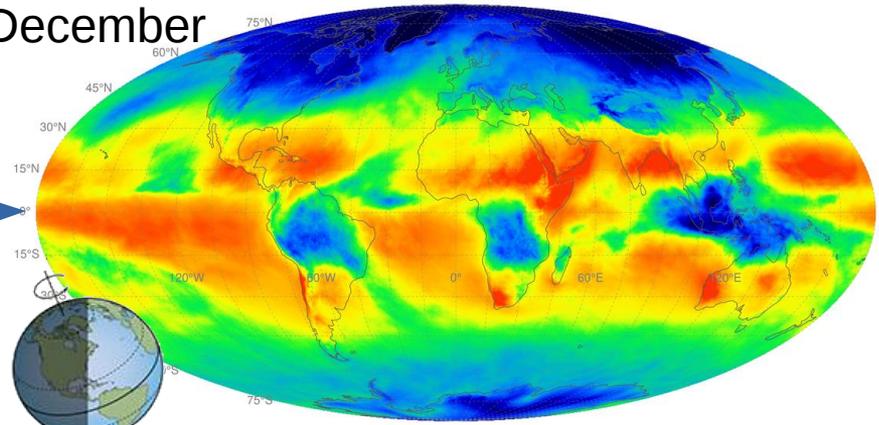
September



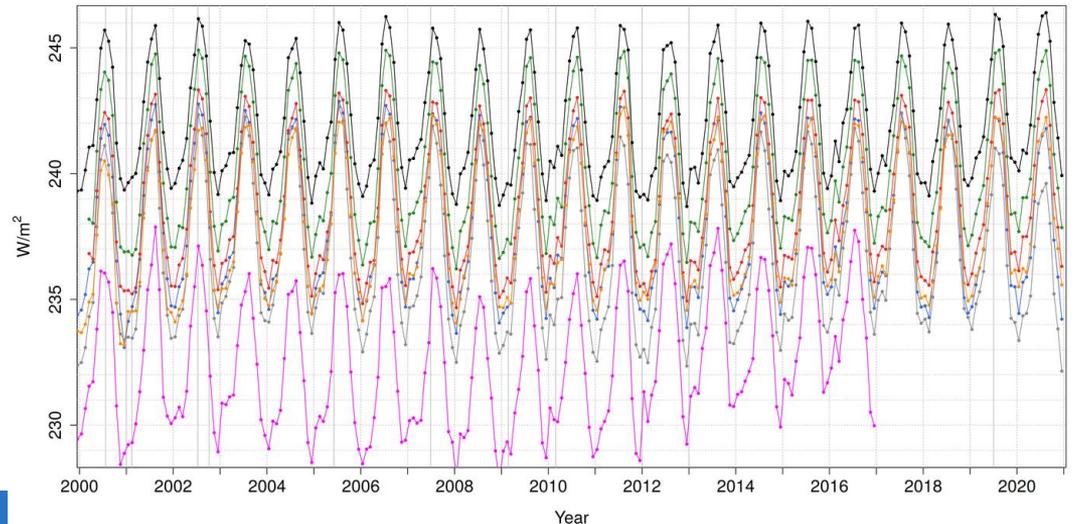
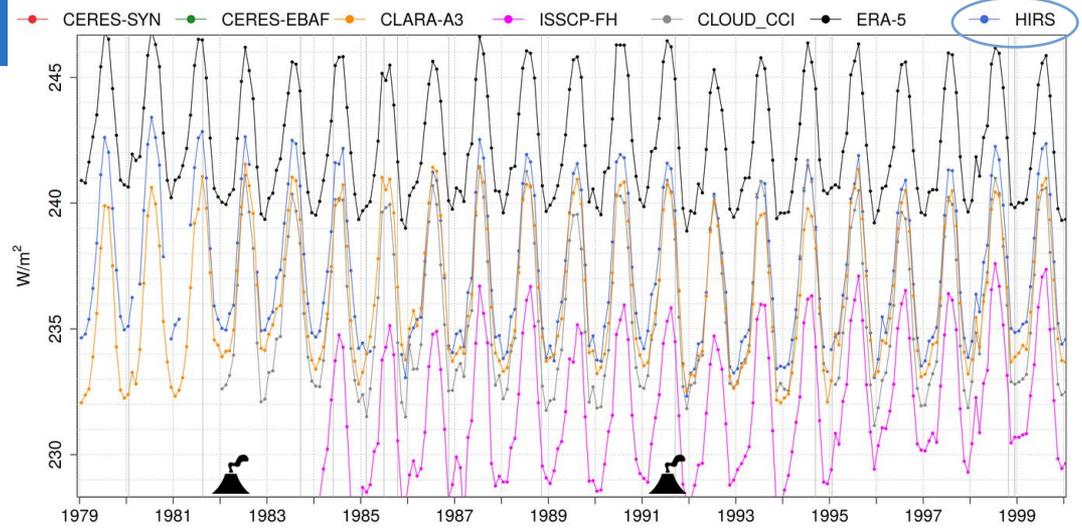
CLARA-A3 TOA LW radiation (200812)

Mean=234.70 W/m²

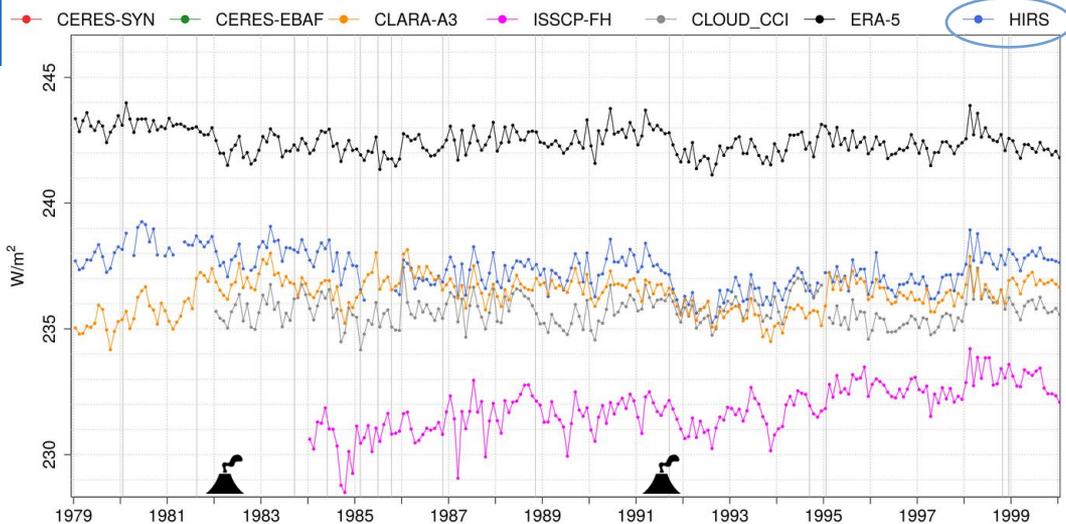
December



• **Global Monthly Mean OLR:**

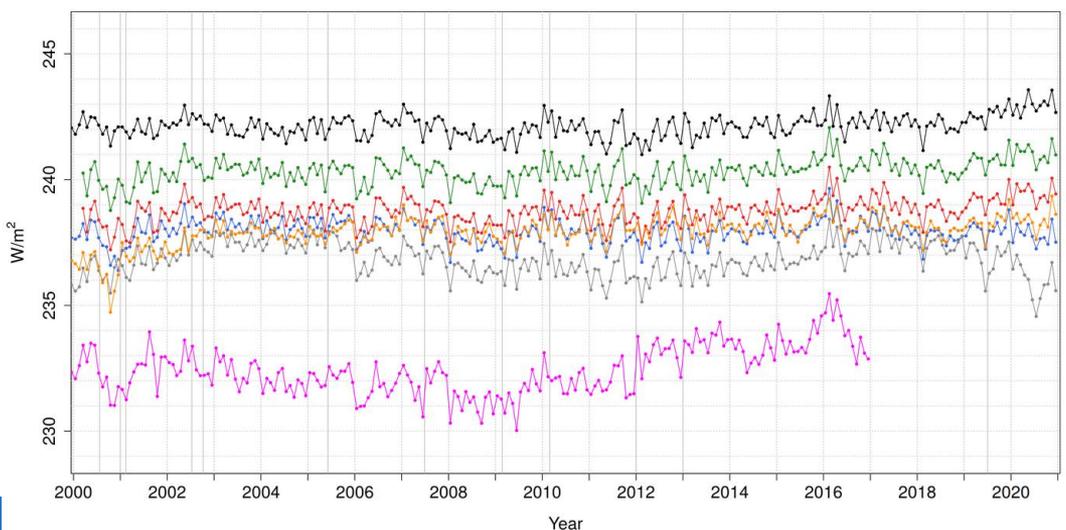


• Global Monthly Mean OLR:



▲ Major volcanic events

• Deseasonalized



Trends (W/m²/dec):

Full series:

ERA5:	-0.1125
HIRS:	+0.1461
CLARA-A3:	+0.6321

Since 2000:

ERA5:	+0.2295
HIRS:	-0.0679
CLARA-A3:	+0.3800
CERESSYN:	+0.2825
CERESEBAF:	+0.2839

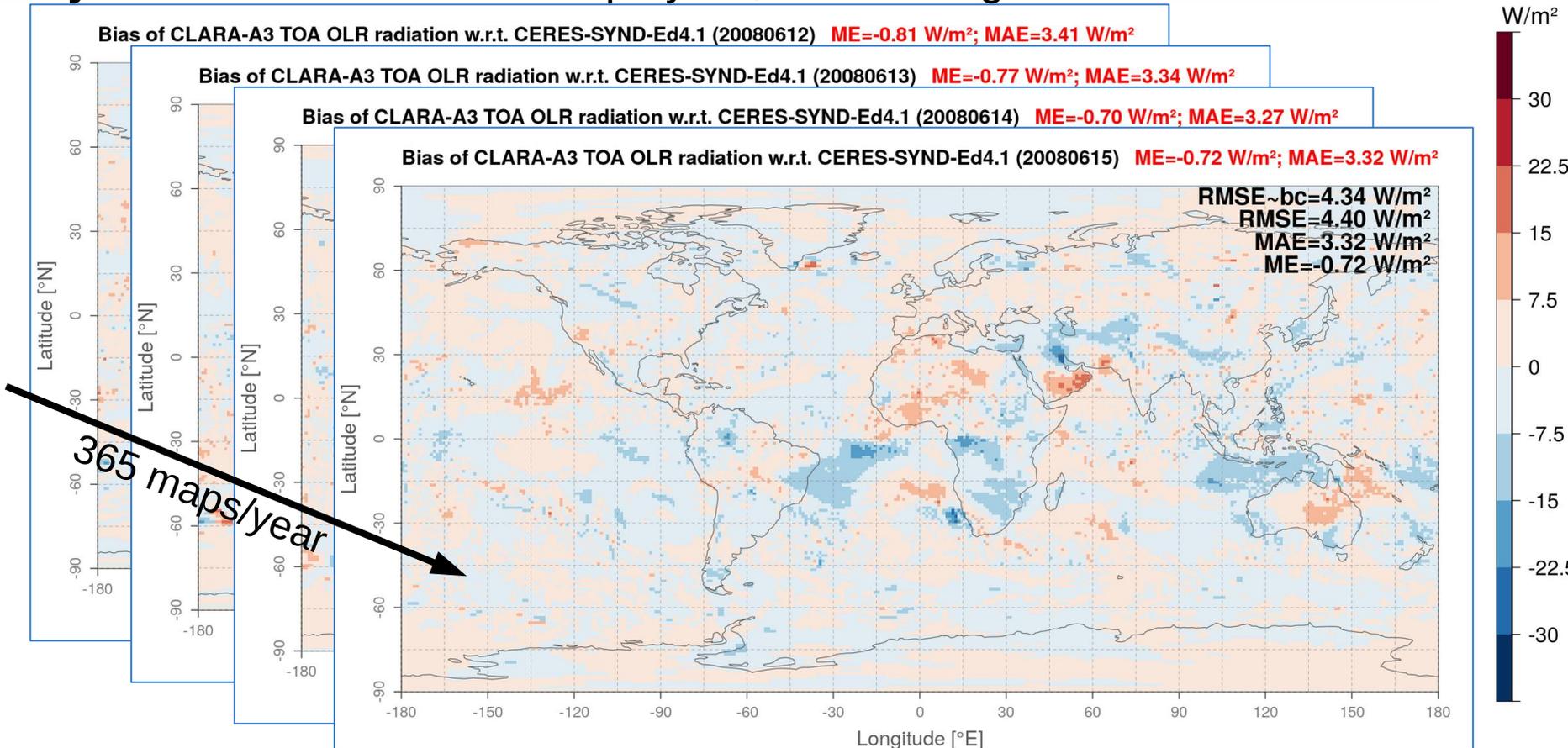
- **Longwave: Outgoing Longwave Radiation :**

- **Bias:**
 - Daily mean OLR
 - Monthly mean OLR
- **RMSE (bias corrected):**
 - Daily mean OLR
 - Monthly mean OLR

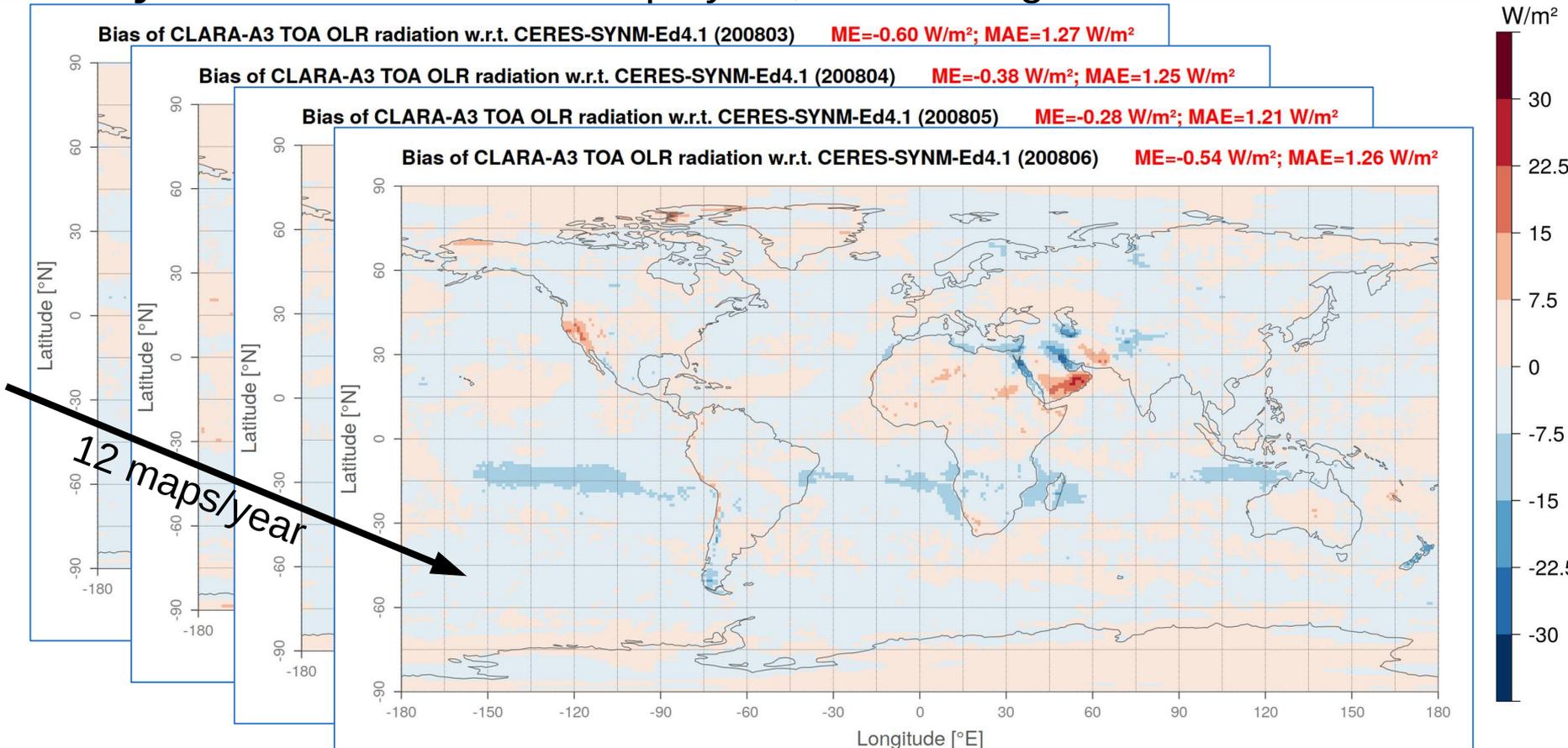
- **Shortwave: Reflected Solar Flux :**

- **Bias:**
 - Daily mean RSF
 - Monthly mean RSF
- **RMSE (bias corrected):**
 - Daily mean RSF
 - Monthly mean RSF

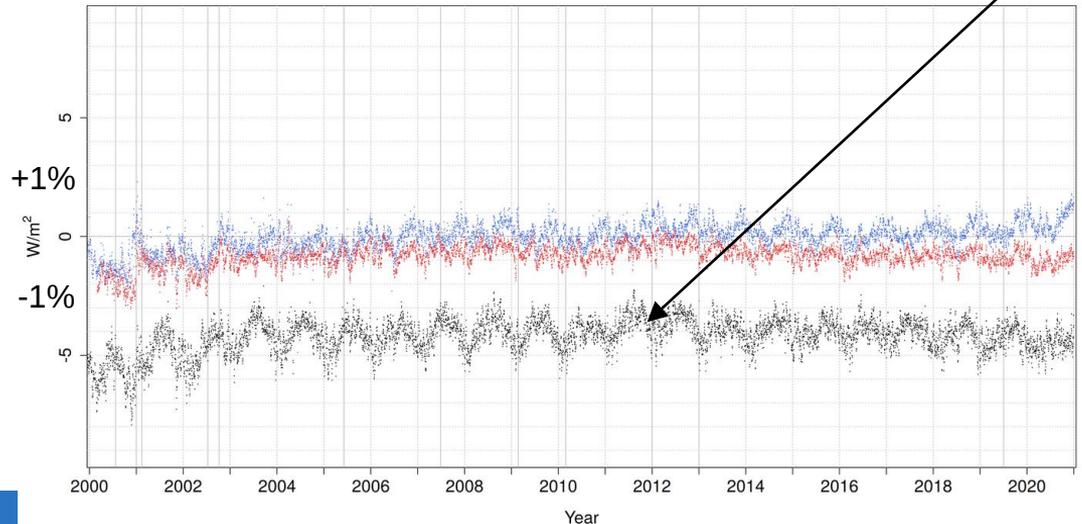
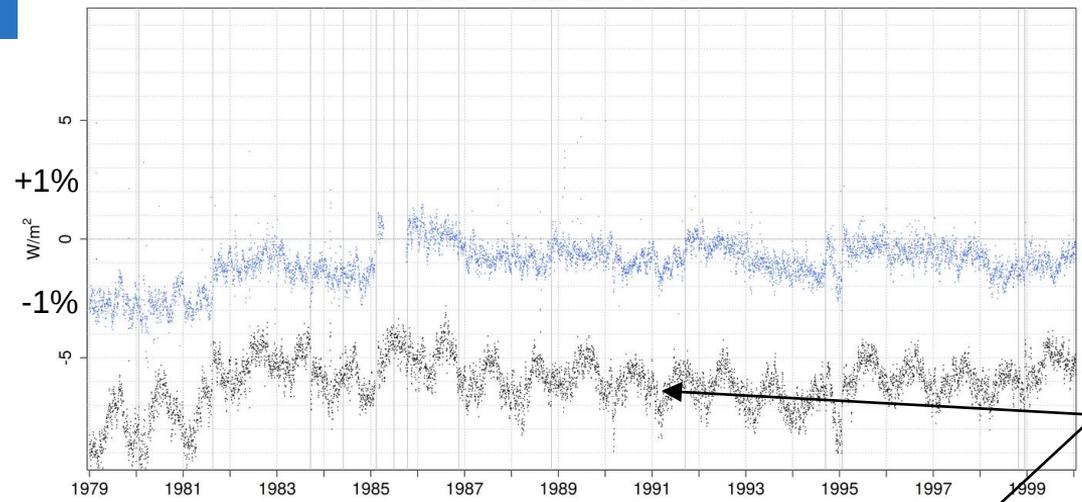
Daily mean OLR: 365 bias maps/year, each with global bias and RMSE:



- Monthly mean OLR: 12 bias maps/year, each with global bias and RMSE:**



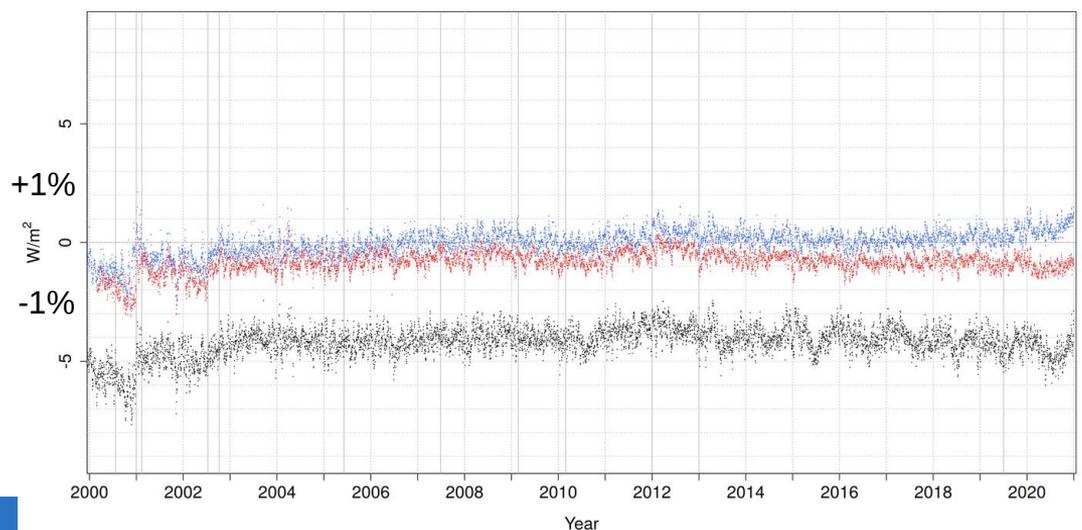
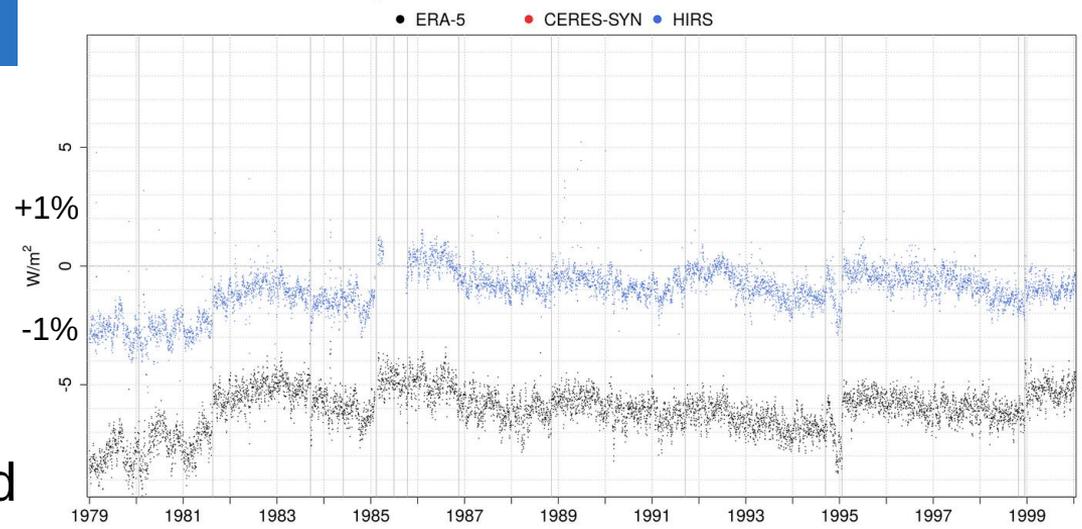
• Global mean bias of Daily Mean OLR:



Bias w.r.t. **ERA5** has a systematic seasonal pattern, not visible in biases w.r.t. CERES and HIRS.

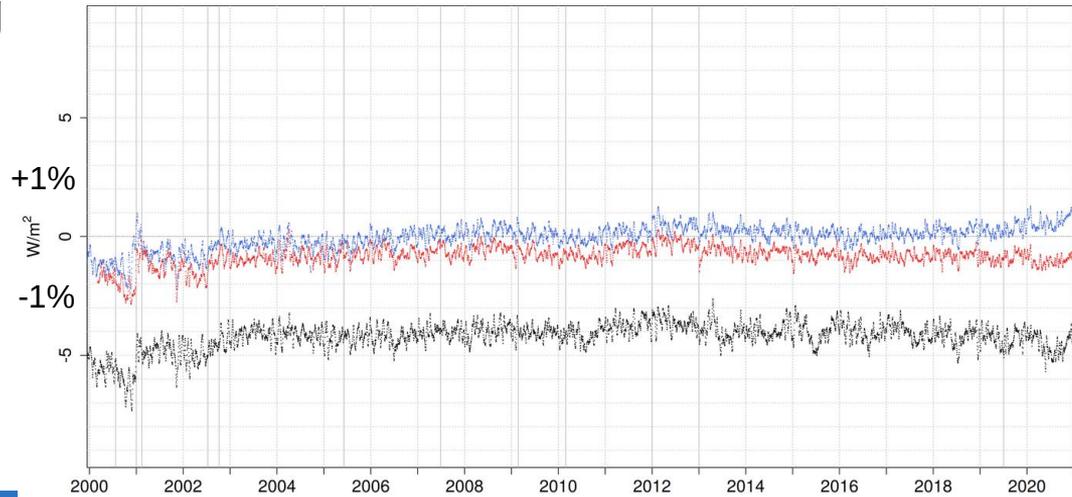
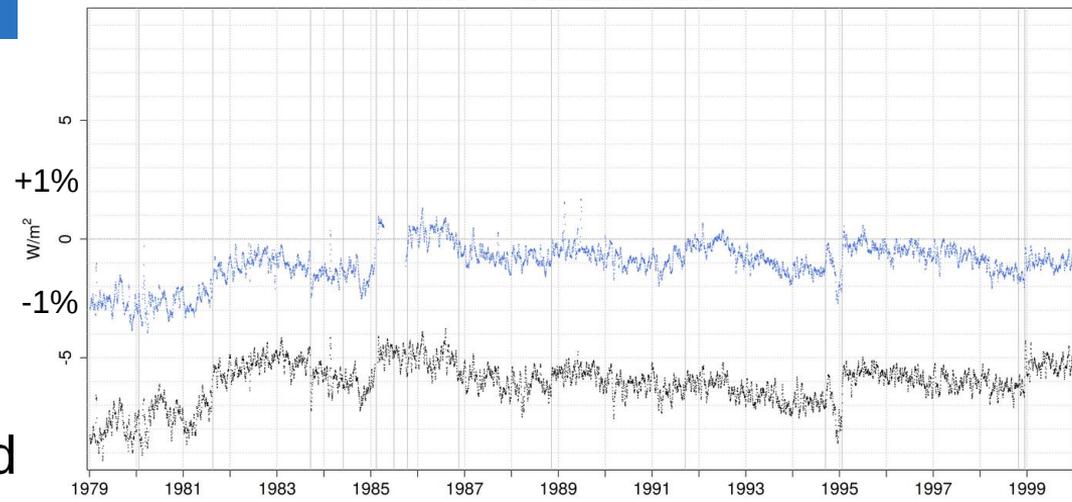
- Global mean bias of Daily Mean OLR:

- Deseasonalized



• Global mean bias of Daily Mean OLR:

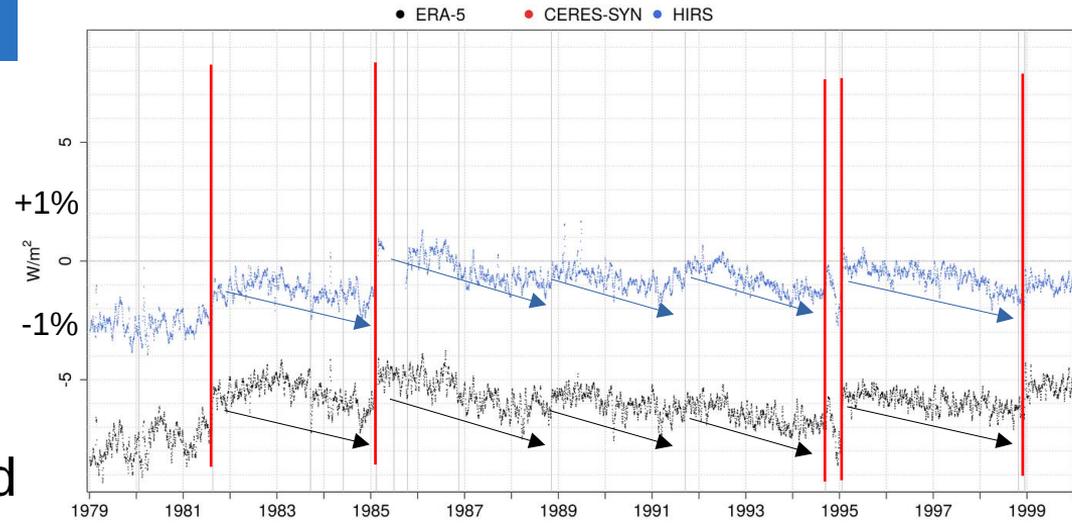
• Deseasonalized
 • Weekly running average



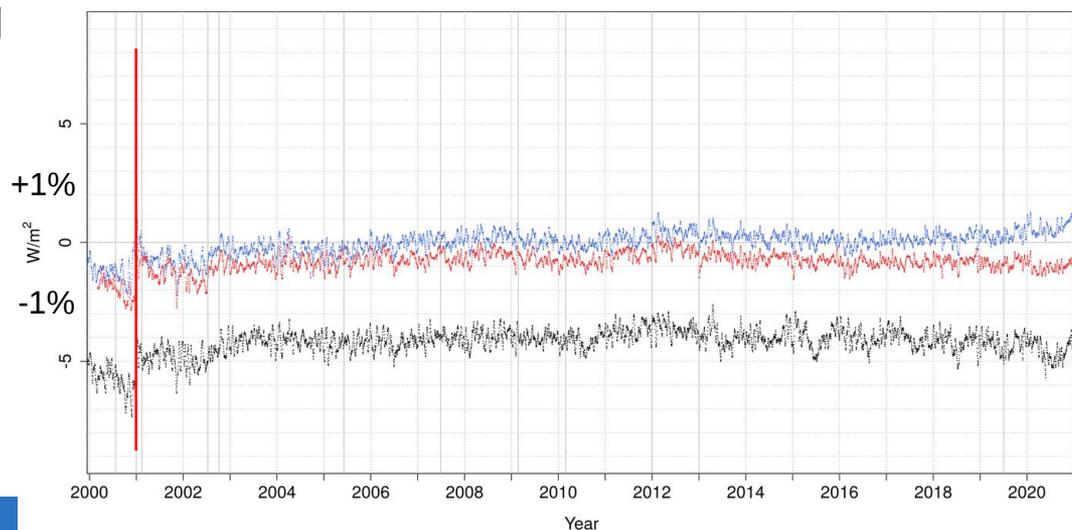
*Overall: good:
 within +/-1% w.r.t.
 HIRS*

• Global mean bias of Daily Mean OLR:

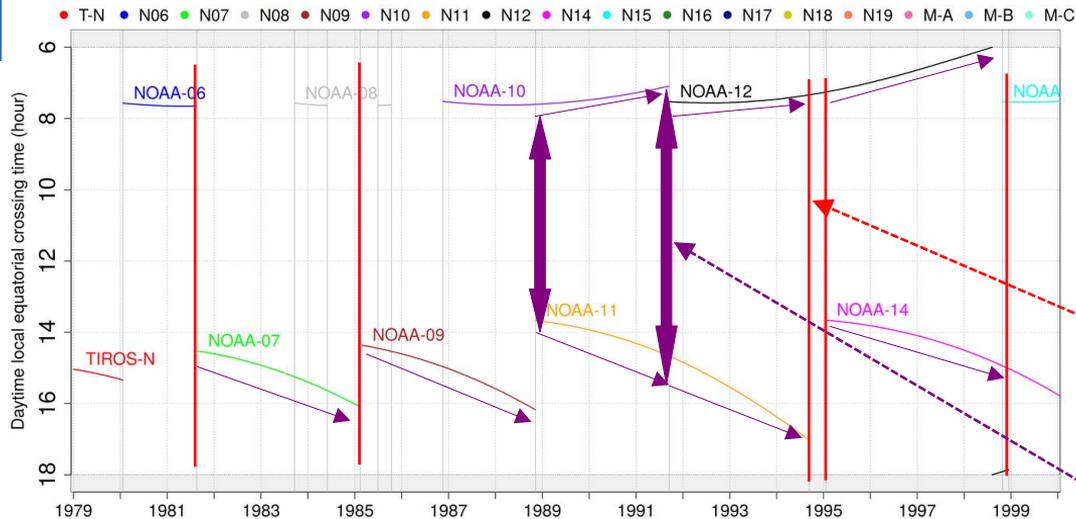
• Deseasonalized
 • Weekly running average



Discontinuities related to changes in orbital configuration?

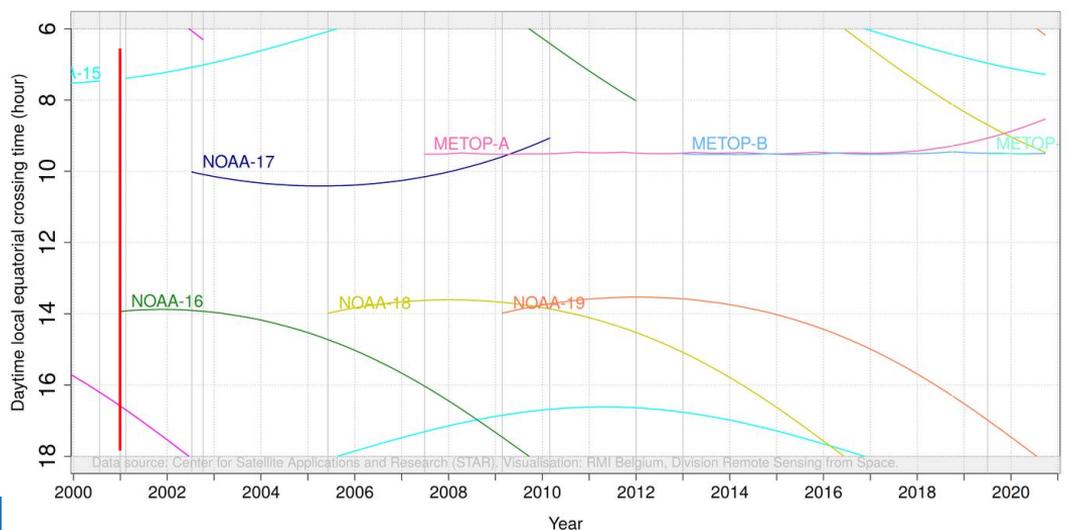


Daytime local equatorial crossing time of satellites used for CLARA-A3



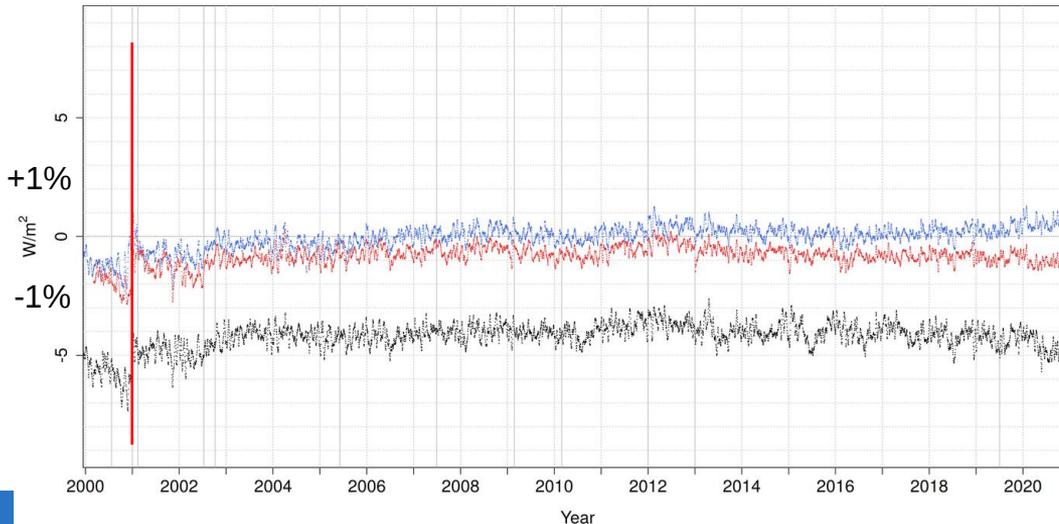
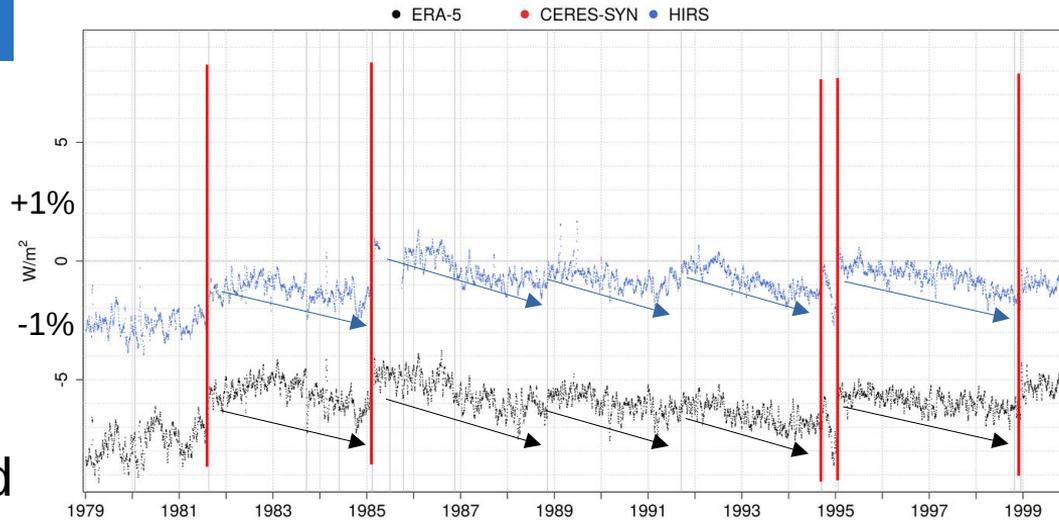
Orbital discontinuities
 +

Between the discontinuities are gradients from small to large temporal spread of observations



- **Global mean bias of Daily Mean OLR:**

- Deseasonalized
- Weekly running average

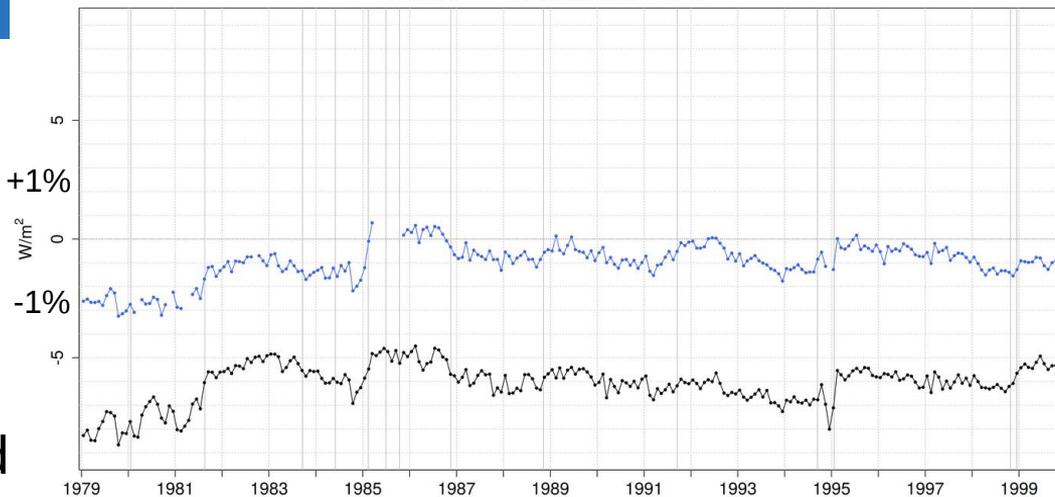


• **Global mean bias of Monthly Mean OLR:**

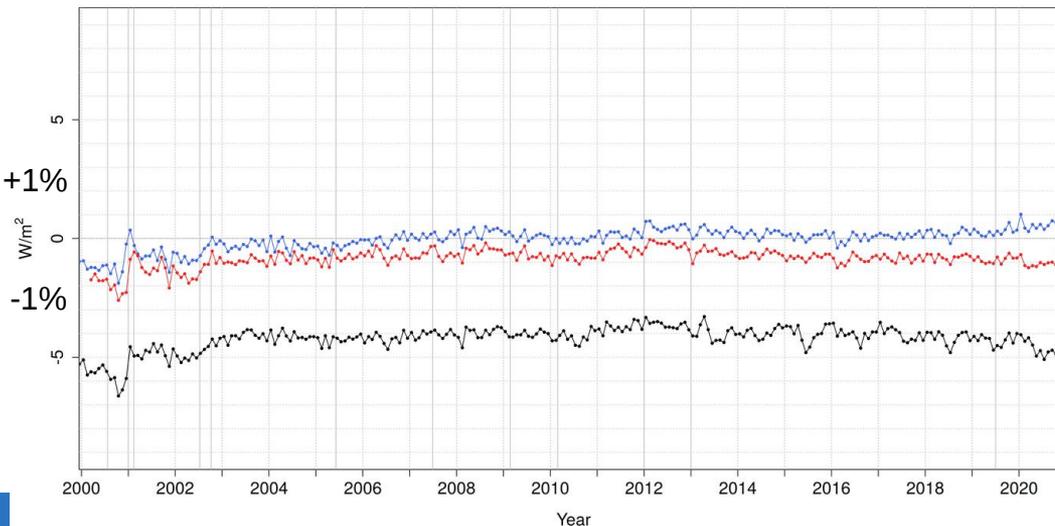
• **Deseasonalized**

Global monthly bias of CLARA-A3 OLR w.r.t. other data records

• ERA-5 • CERES-SYN • HIRS



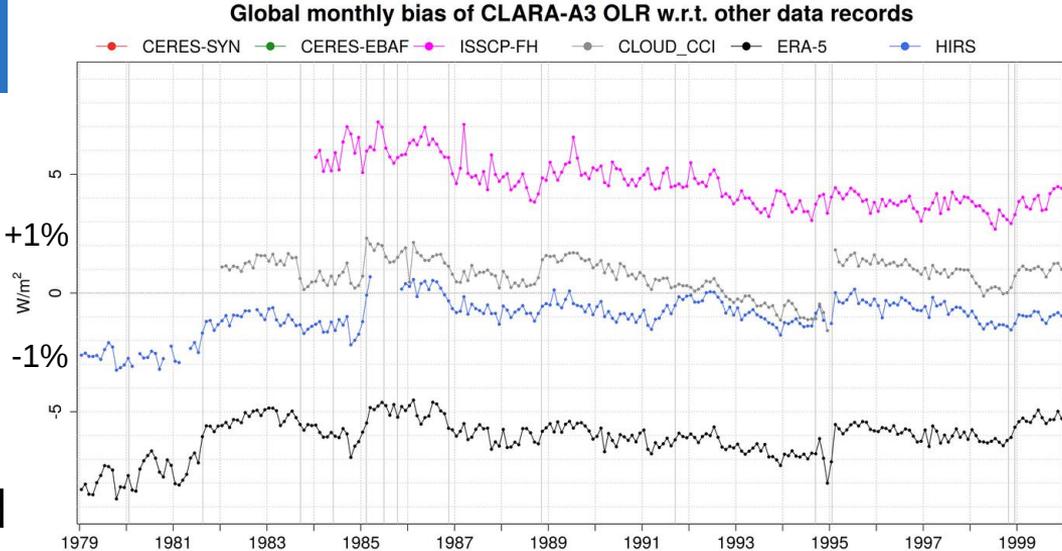
Monthly pattern same as daily.



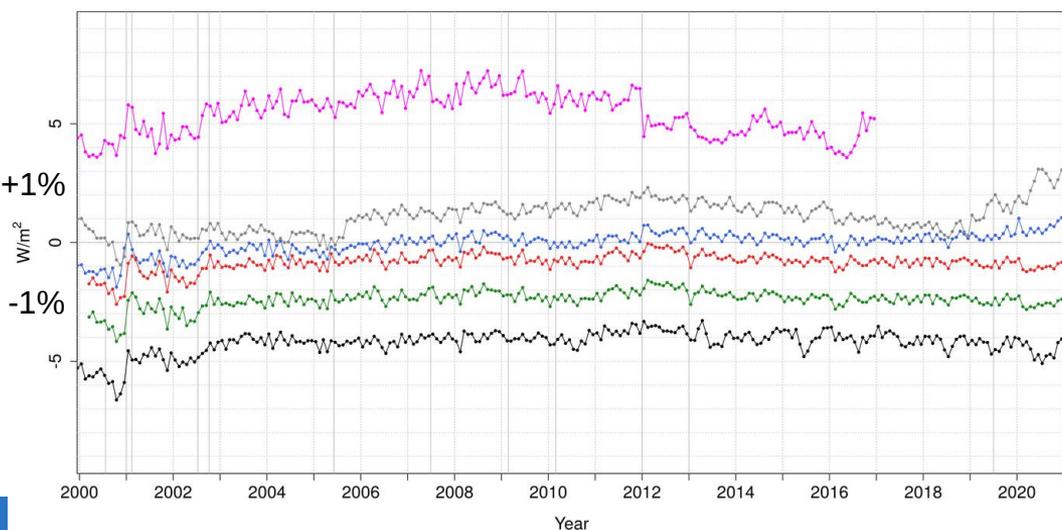
Stable w.r.t. HIRS

• **Global mean bias of Monthly Mean OLR:**

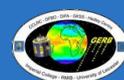
• **Deseasonalized**



Monthly pattern same as daily.

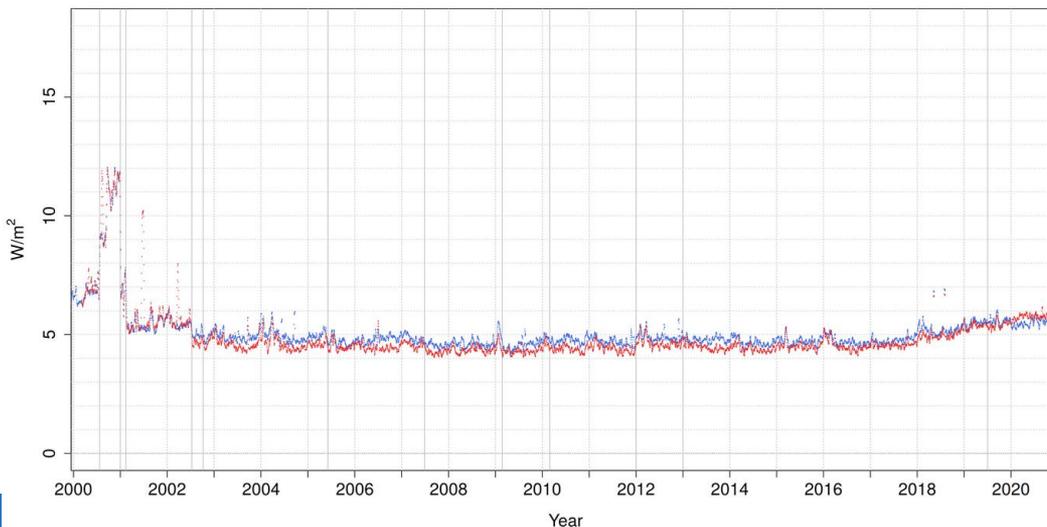
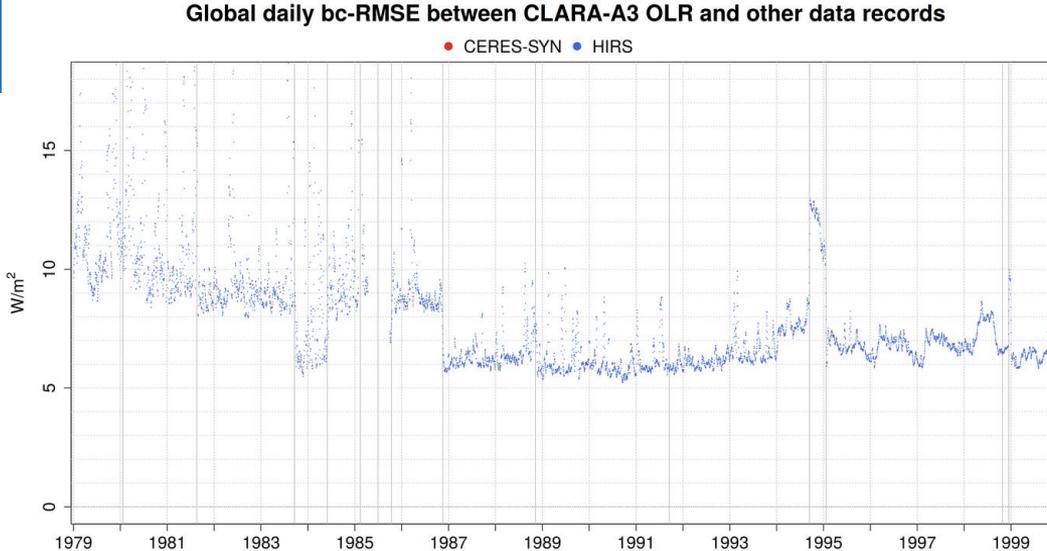


Stable w.r.t. CERES SYN/EBAF



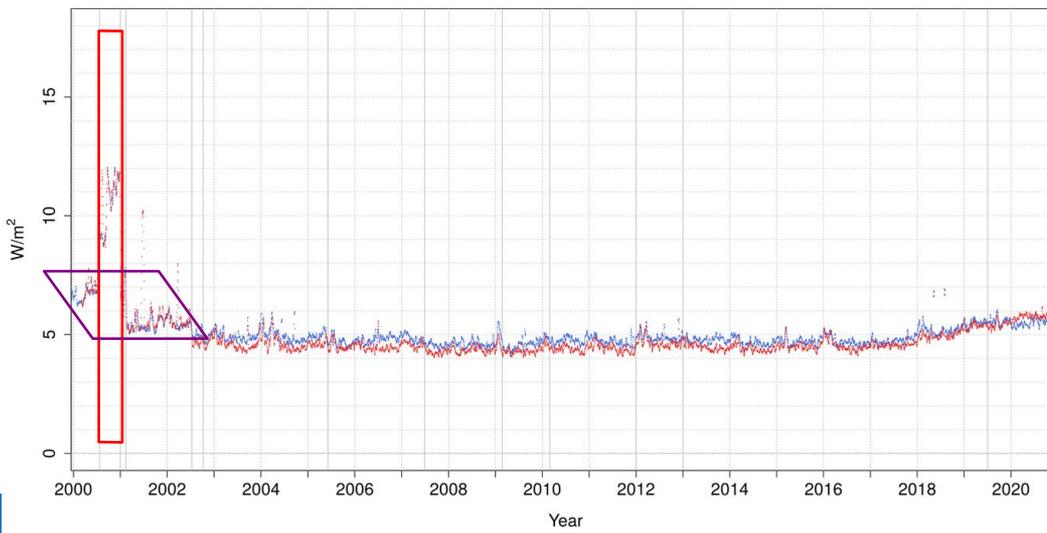
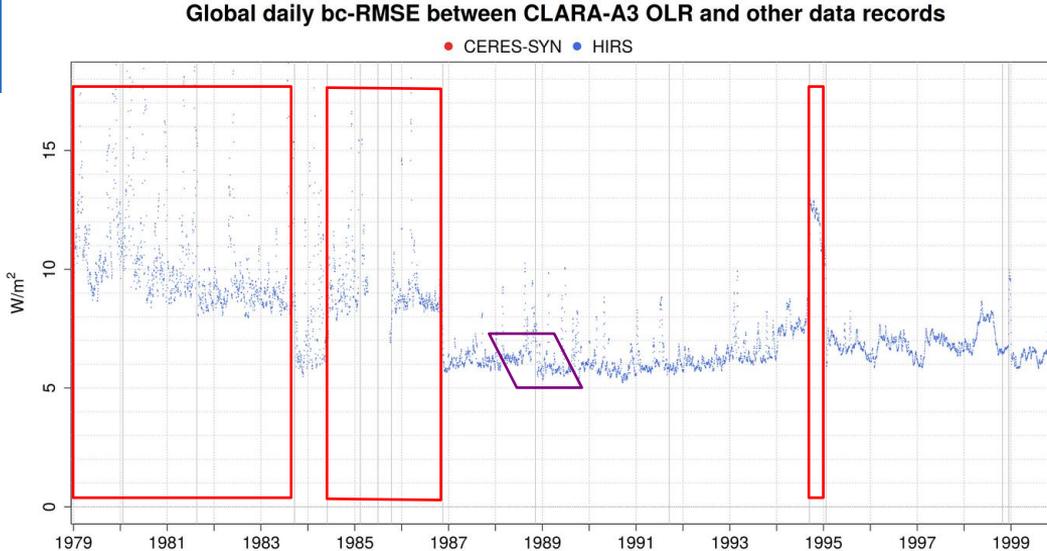
- Global RMSE
(bias-
corrected) of
Daily Mean
OLR:

- Weekly running average



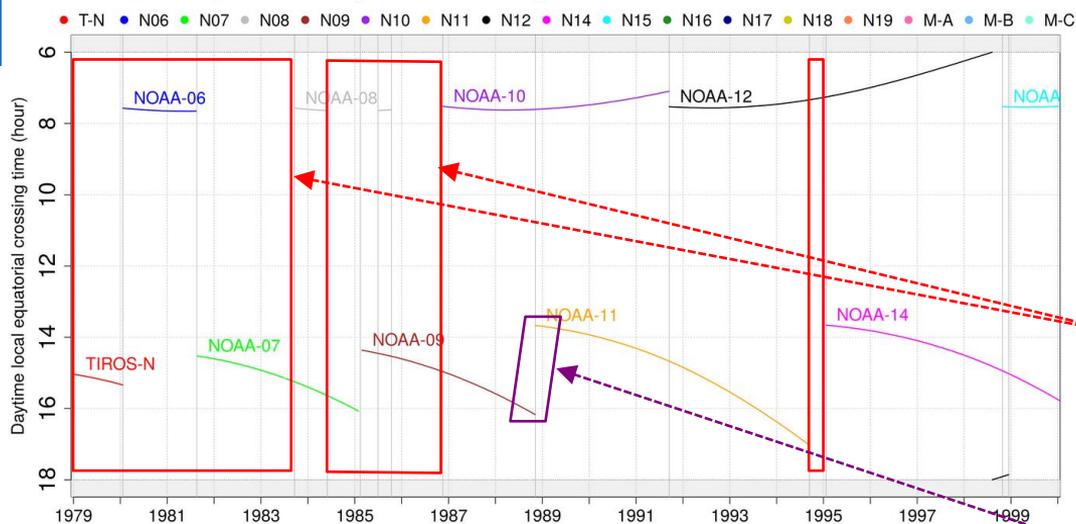
- **Global RMSE (bias-corrected) of Daily Mean OLR:**

- **Weekly running average**



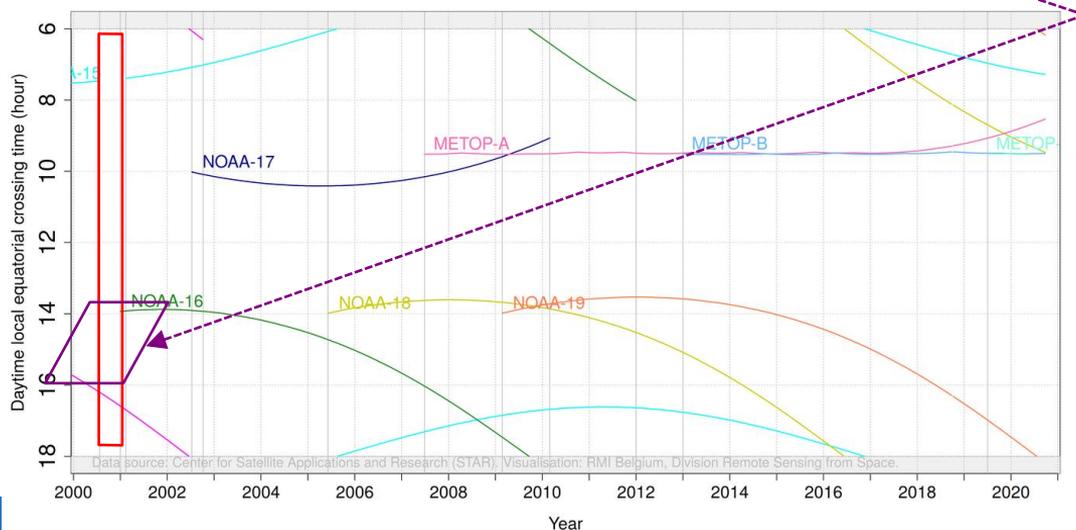
Discontinuities due to changed orbital configuration.

• **Orbital configuration of CLARA-A3:**

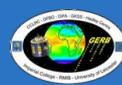


Discontinuities due to changed orbital configuration:

Single-orbit periods (either morning or afternoon)



Discontinuities between satellites and hence local solar time

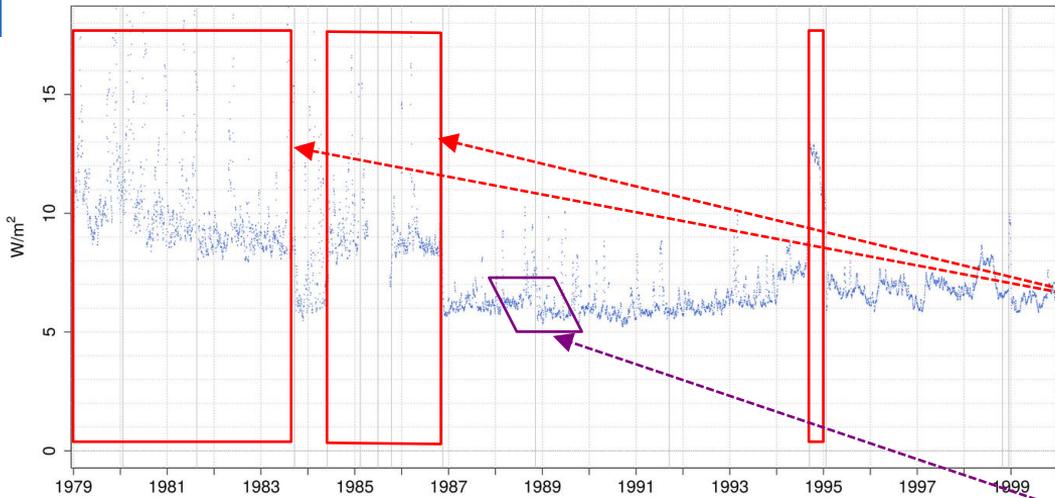


• **Global RMSE (bias-corrected) of Daily Mean OLR:**

• **Weekly running average**

Global daily bc-RMSE between CLARA-A3 OLR and other data records

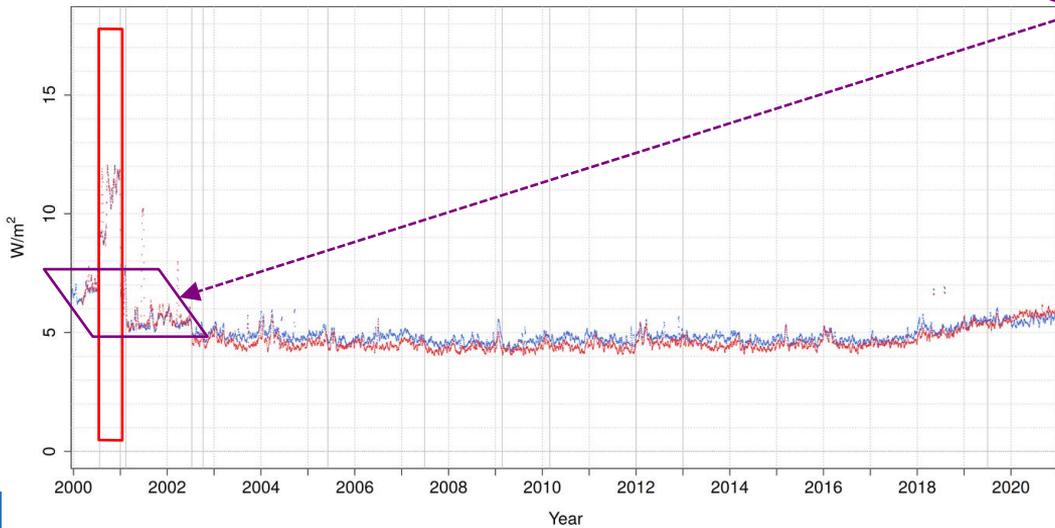
● CERES-SYN ● HIRS



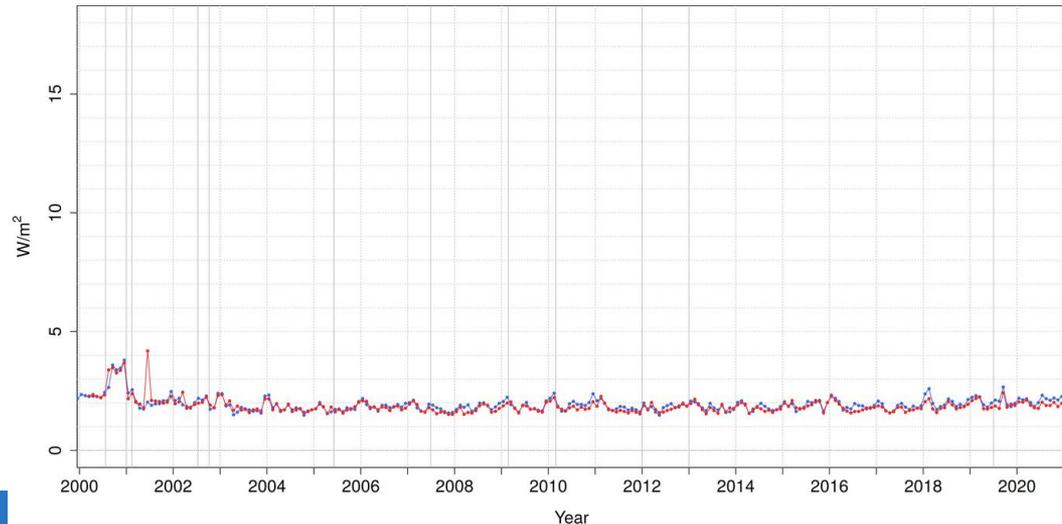
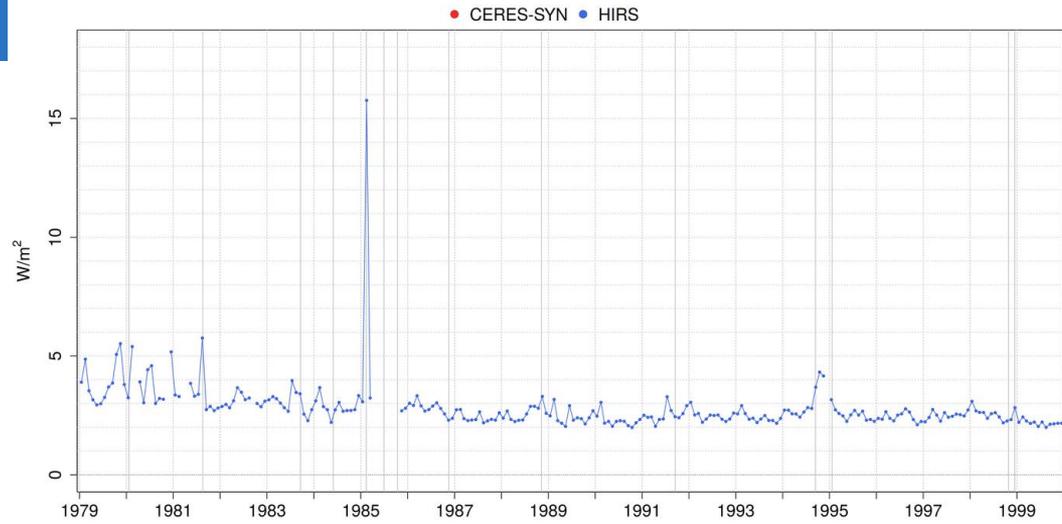
Discontinuities due to changed orbital configuration:

Single-orbit periods (either morning or afternoon)

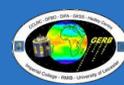
Discontinuities between satellites and hence local solar time



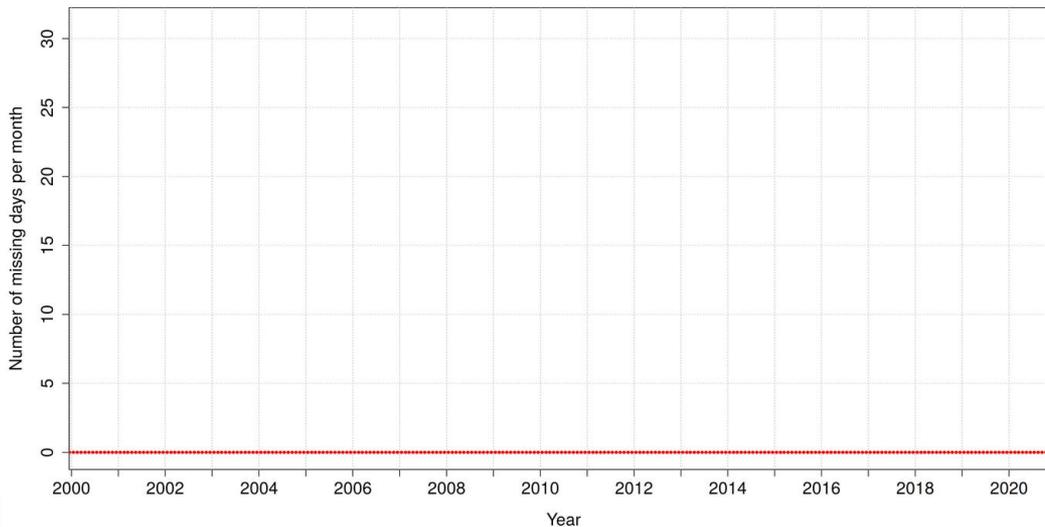
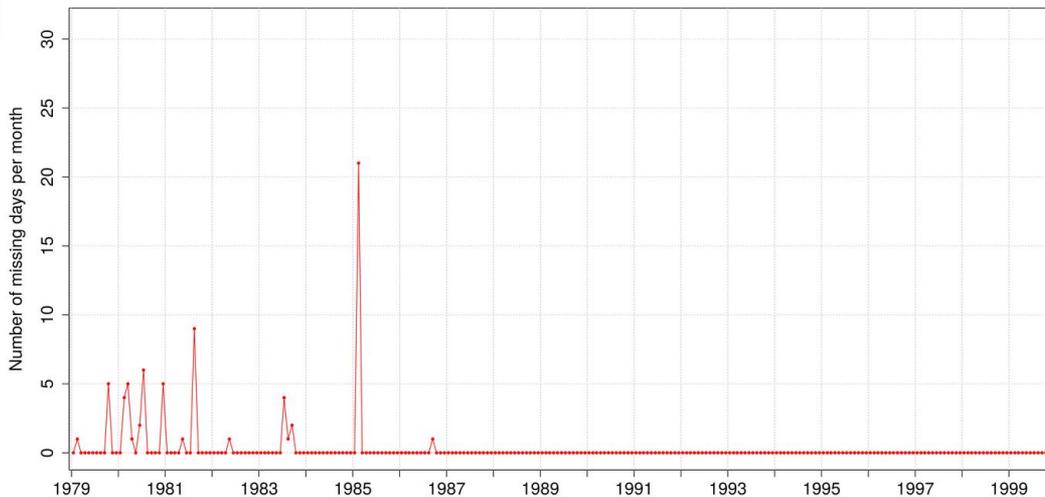
• **Global RMSE**
(bias-
corrected) of
Monthly Mean
OLR:



On monthly scale,
 impact of orbital
 configuration is
 much smaller.

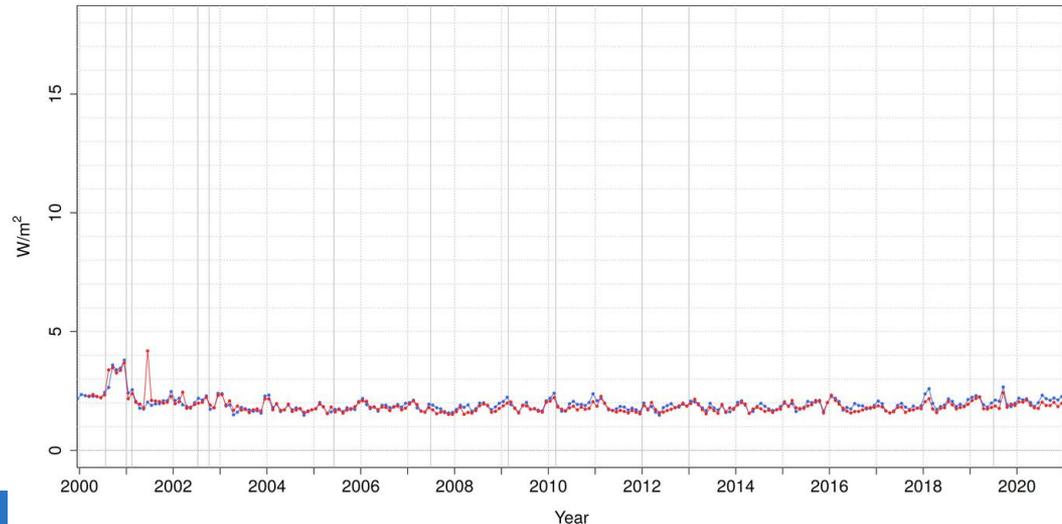
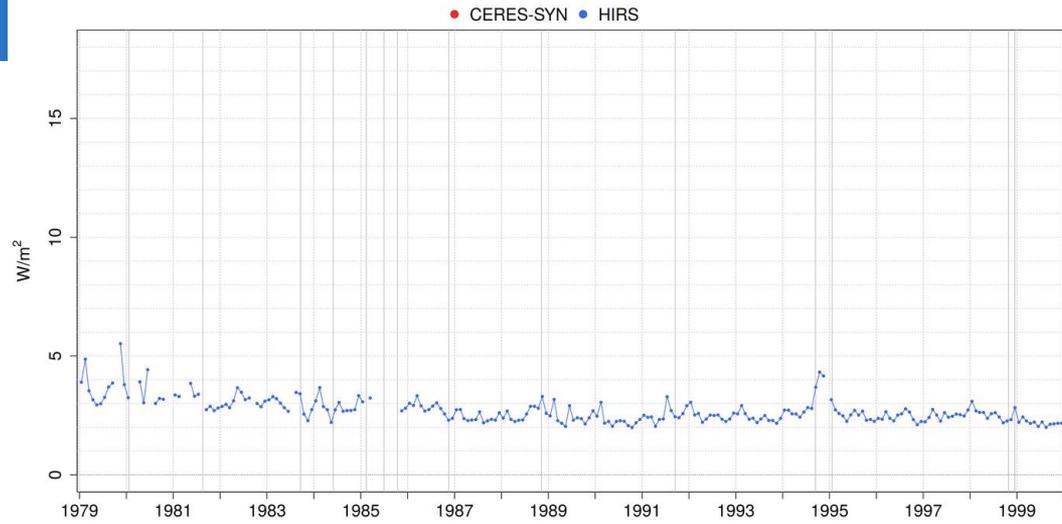


- Global RMSE (bias-corrected) of Daily Mean OLR:



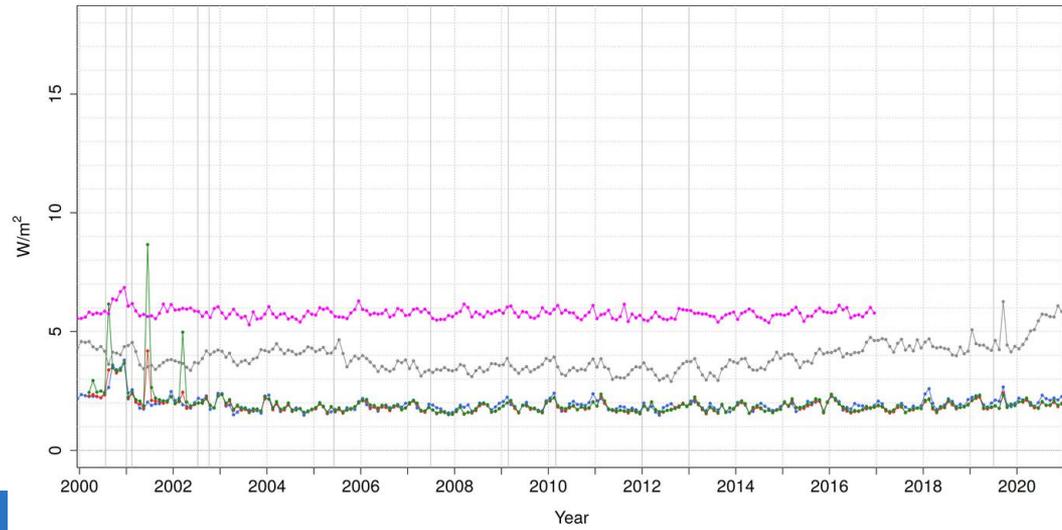
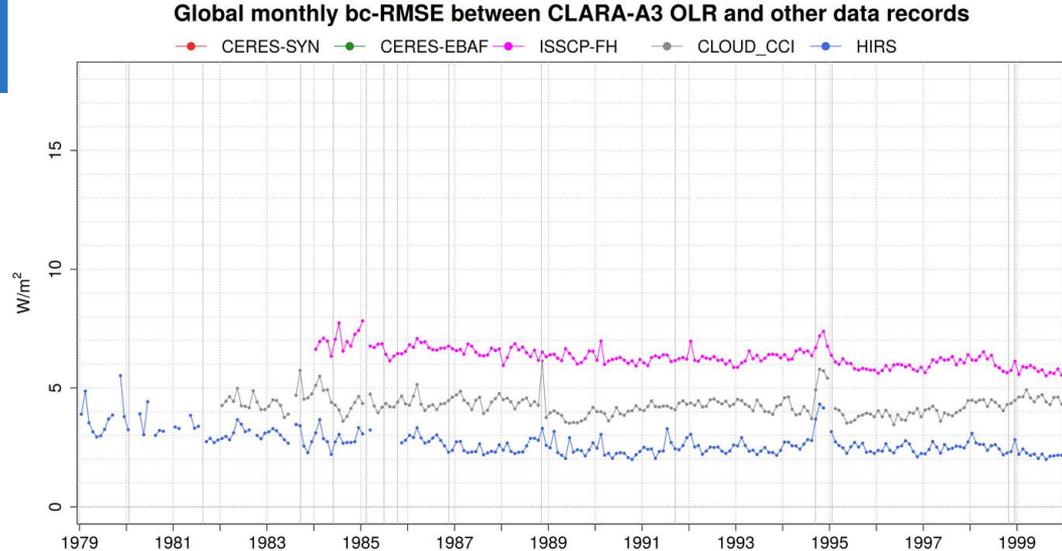
- **Global RMSE (bias-corrected) of Monthly Mean OLR:**

- Max 2 missing days per month



- **Global RMSE (bias-corrected) of Monthly Mean OLR:**

- Max 2 missing days per month

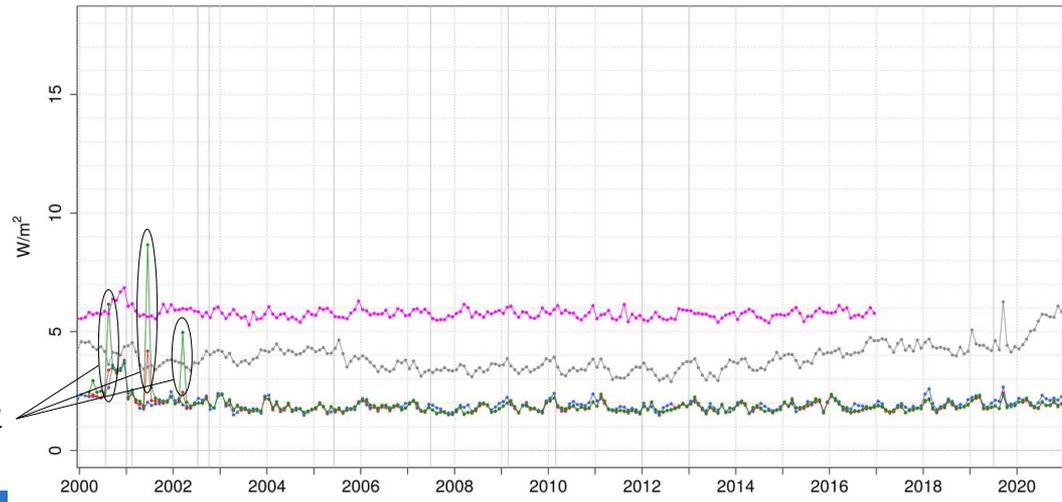
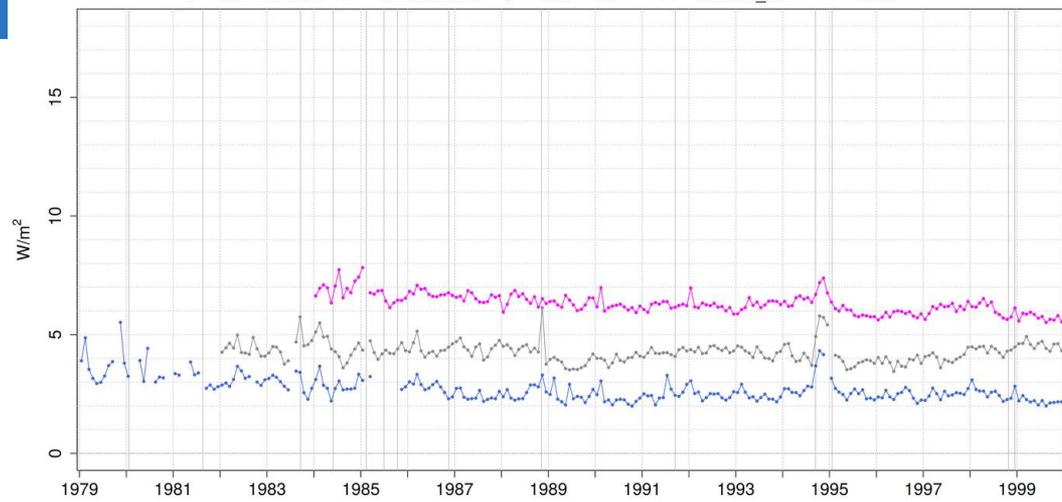


- **Global RMSE (bias-corrected) of Monthly Mean OLR:**

- Max 2 missing days per month

Global monthly bc-RMSE between CLARA-A3 OLR and other data records

— CERES-SYN — CERES-EBAF — ISSCP-FH — CLOUD_CCI — HIRS



Strange artifacts in CERES Ed4.1

- Longwave: Outgoing Longwave Radiation :

- Bias:

- Daily mean OLR
- Monthly mean OLR

- RMSE (bias corrected):

- Daily mean OLR
- Monthly mean OLR

- Shortwave: Reflected Solar Flux :

- Bias:

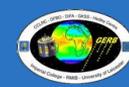
- Daily mean RSF
- Monthly mean RSF

- RMSE (bias corrected):

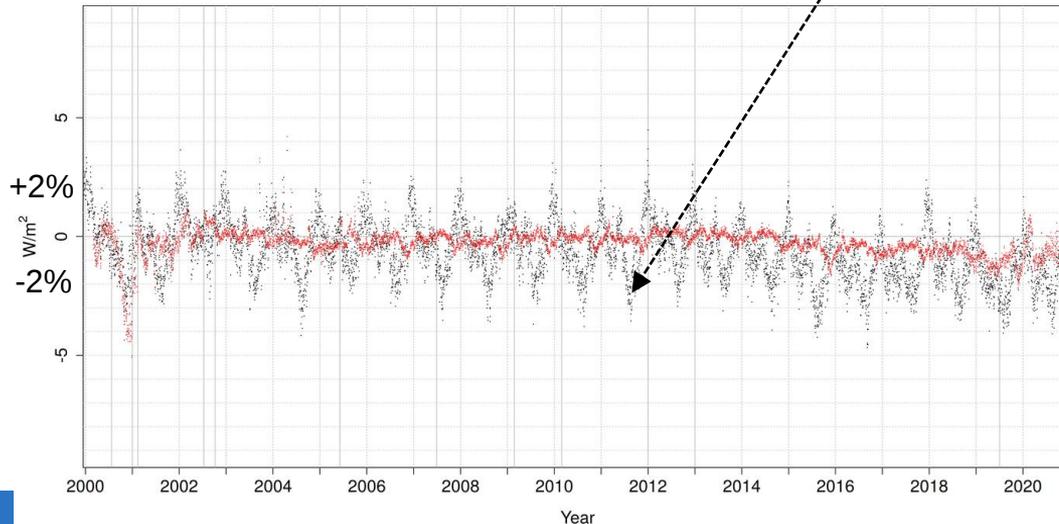
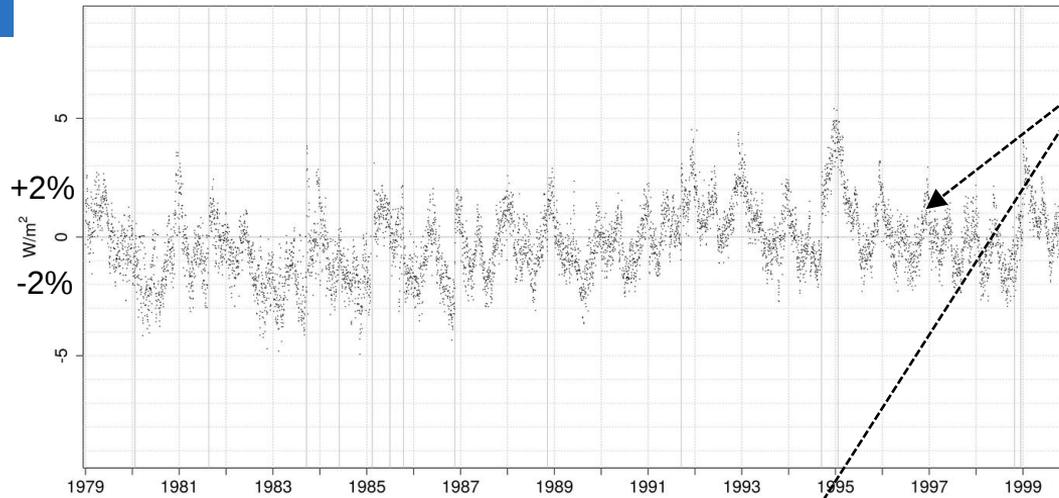
- Daily mean RSF
- Monthly mean RSF



● ERA-5 ● CERES-SYN



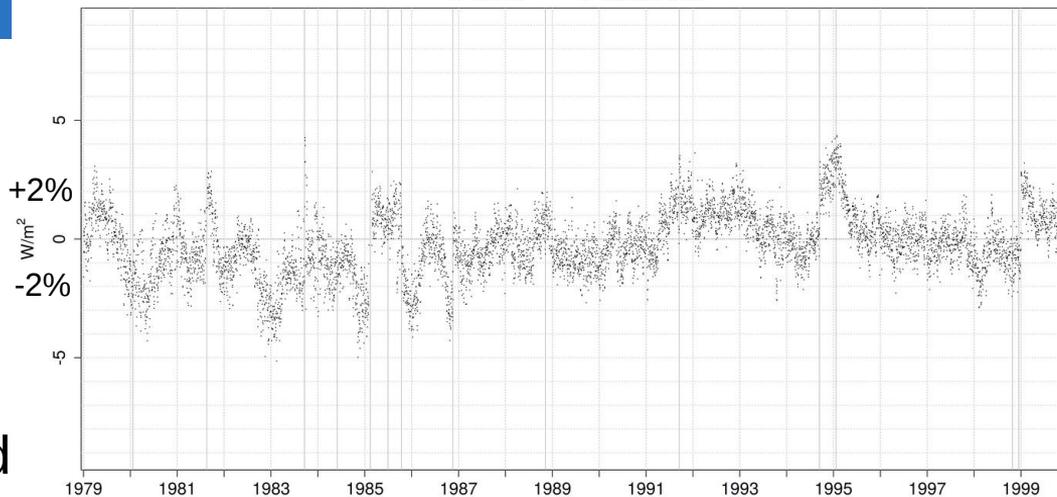
• Global mean bias of Daily Mean RSF:



ERA5 has a systematic seasonal bias w.r.t. CERES and CLARA-A3.

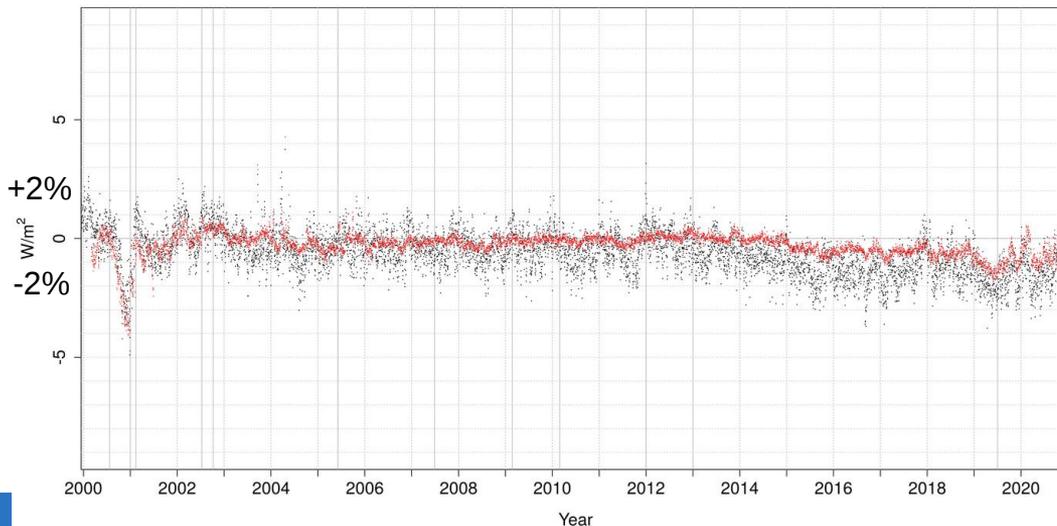
• Global mean bias of Daily Mean RSF:

• Deseasonalized



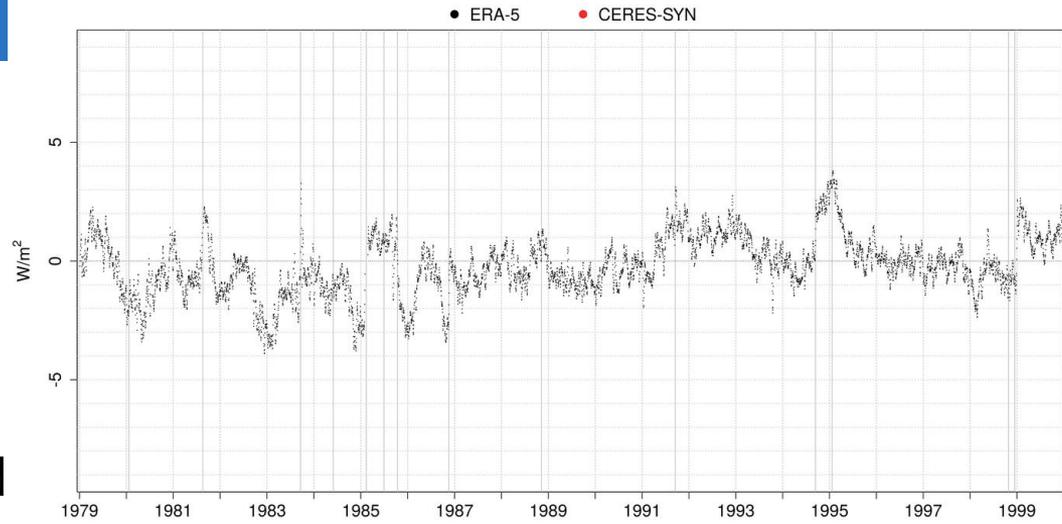
ERA5 has a systematic seasonal bias w.r.t. CERES and CLARA-A3.

This is removed by deseasonalizing.

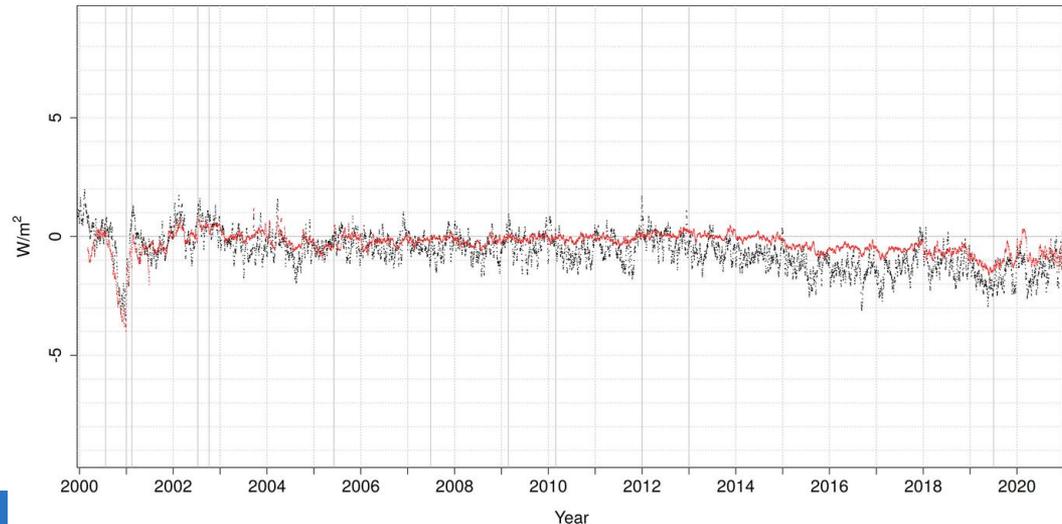


• Global mean bias of Daily Mean RSF:

• Deseasonalized
 • Weekly running average



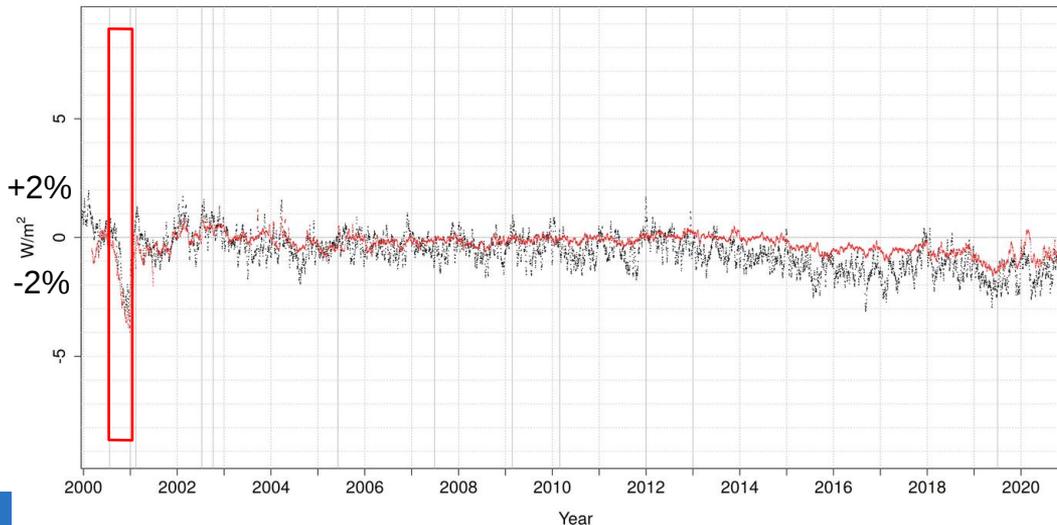
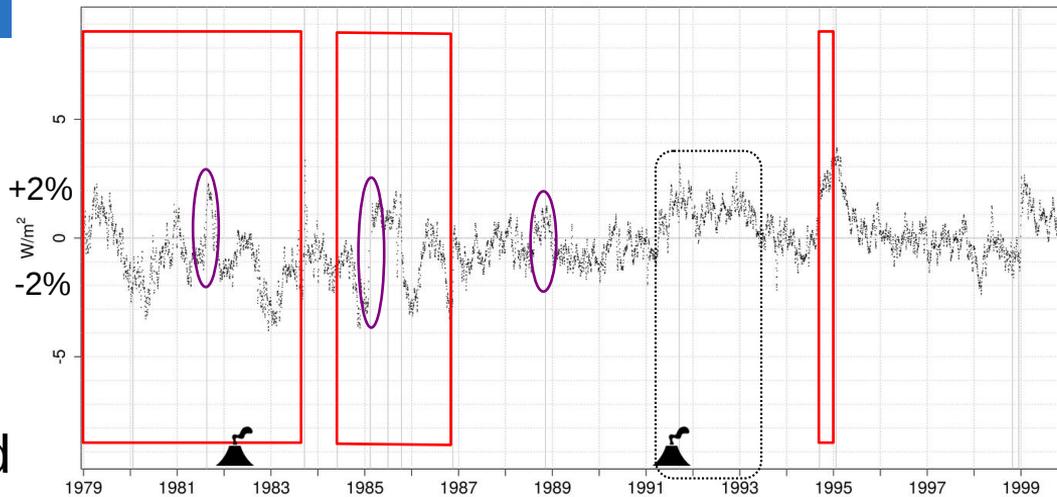
ERA5 has a systematic seasonal bias w.r.t. CERES and CLARA-A3.



This is removed by deseasonalizing.

• **Global mean bias of Daily Mean RSF:**

- Deseasonalized
- Weekly running average

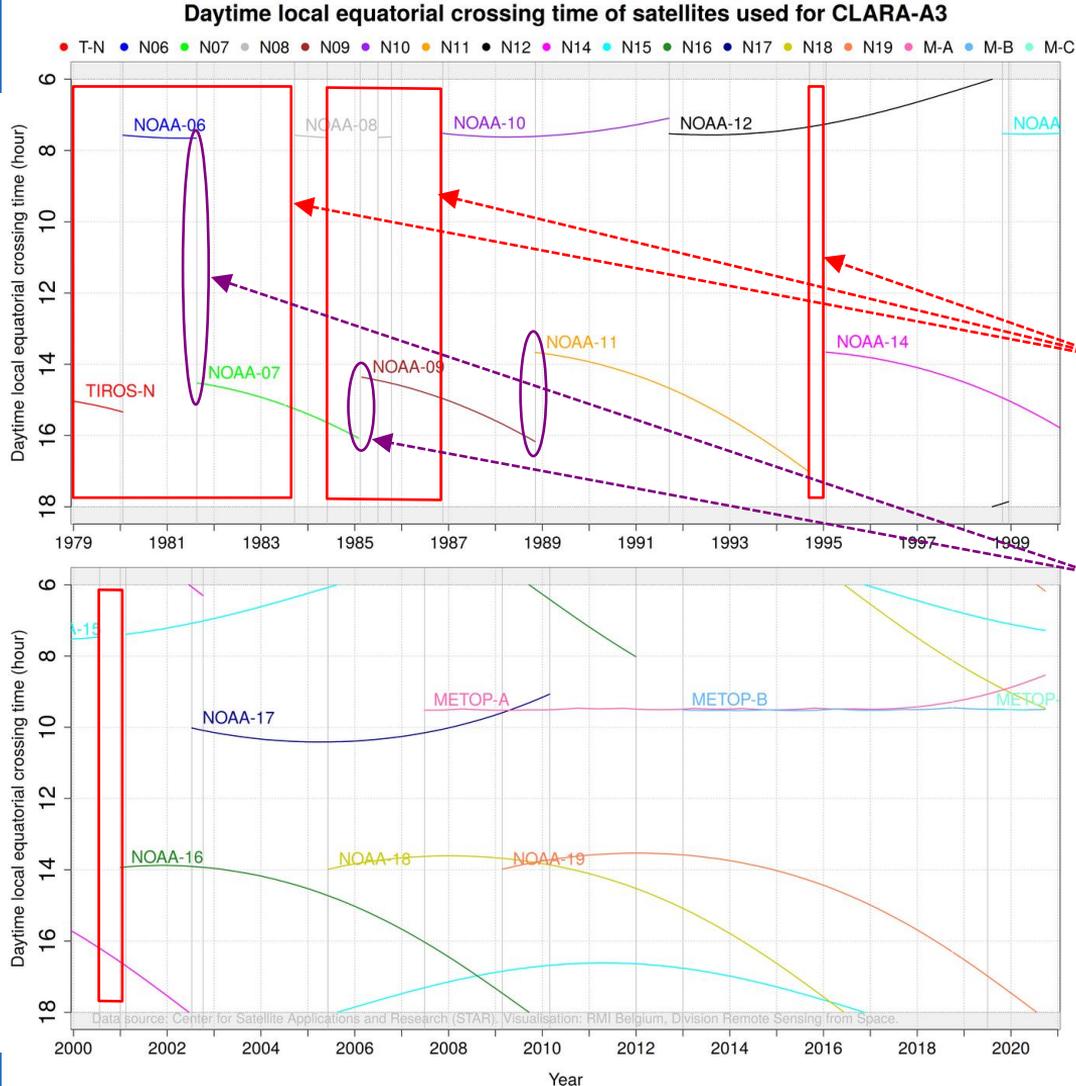


ERA5 has a systematic seasonal bias w.r.t. CERES and CLARA-A3.

This is removed by deseasonalizing.

The remaining bias is due to non-systematic biases in CLARA-A3.

• **Orbital configuration of CLARA-A3:**



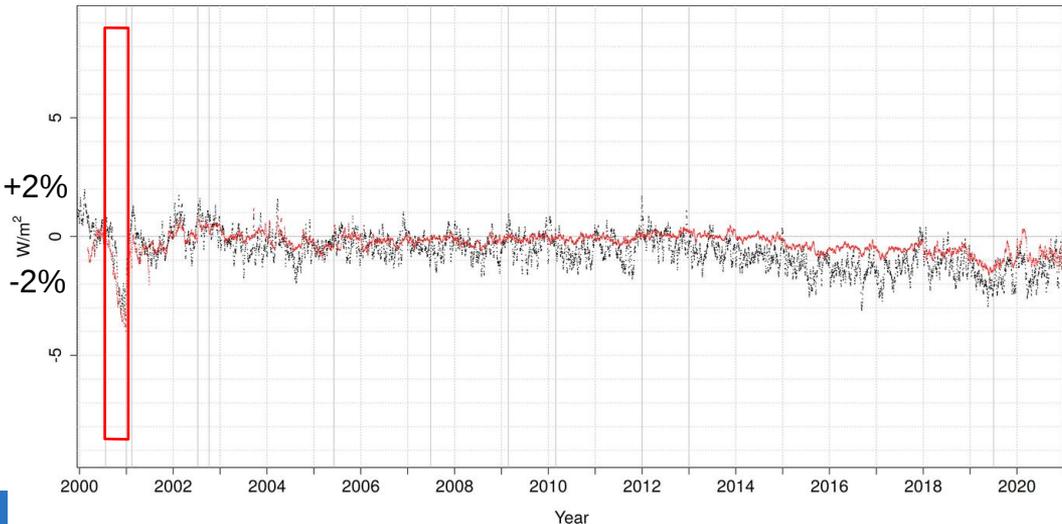
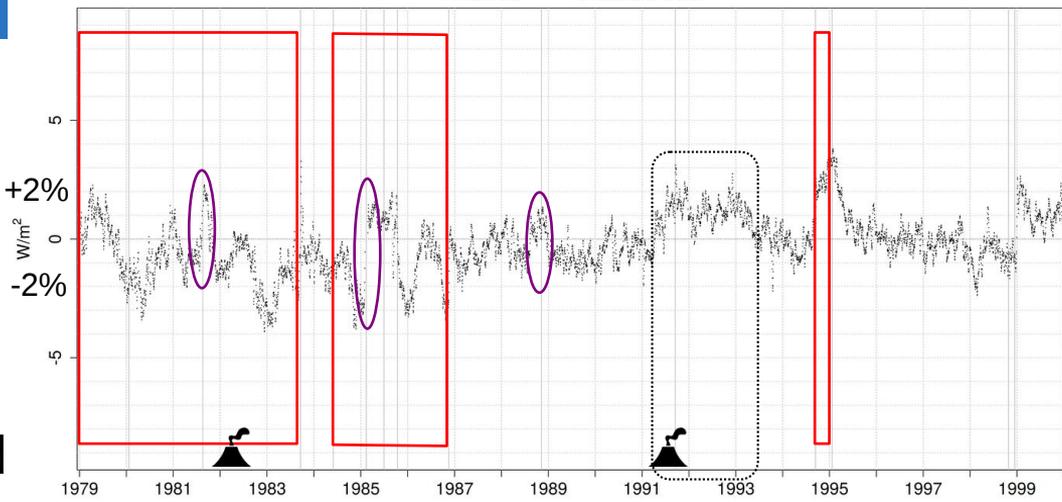
Non-systematic biases in CLARA-A3:

Single-orbit periods (either morning or afternoon)

Discontinuities between satellites and hence local solar time

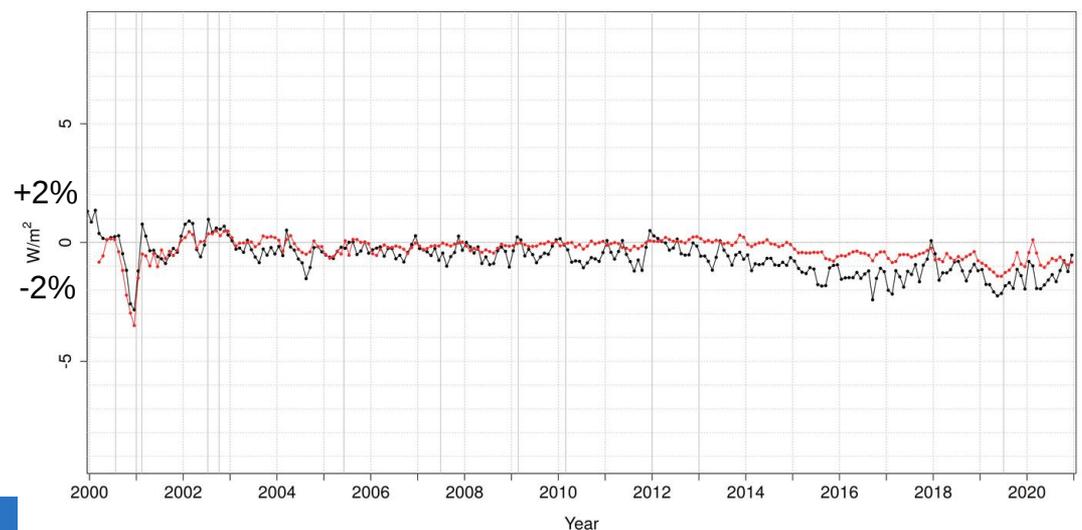
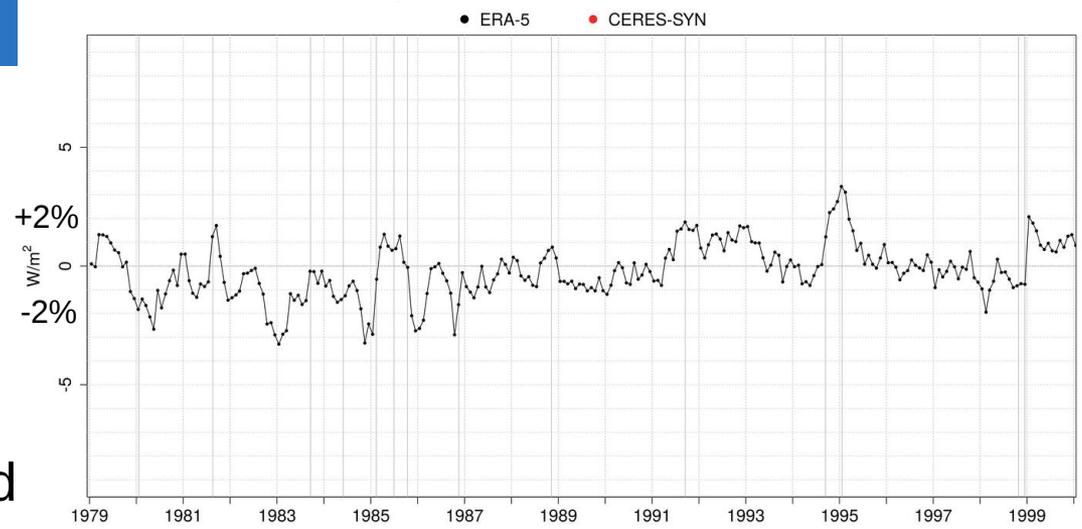
- Global mean bias of Daily Mean RSF:

- Deseasonalized
- Weekly running average



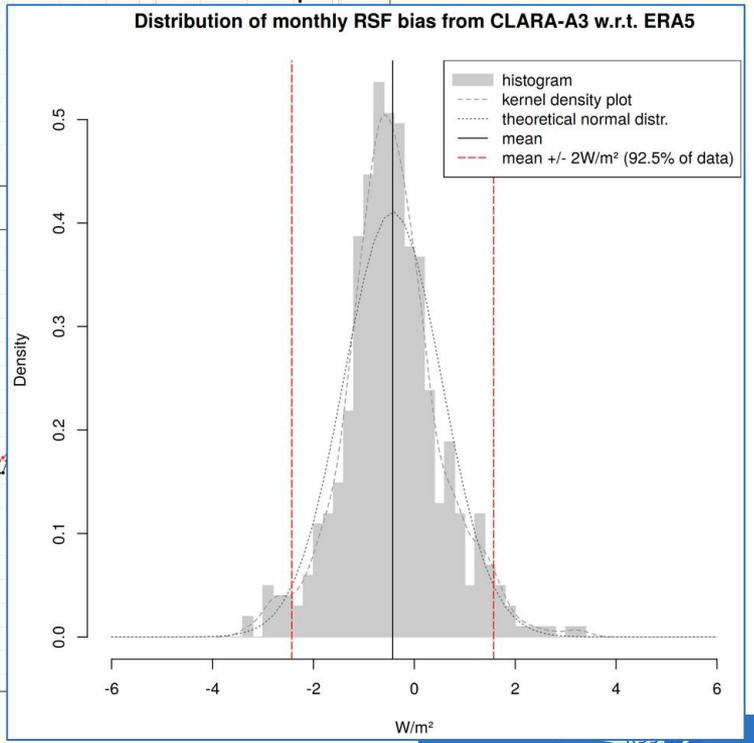
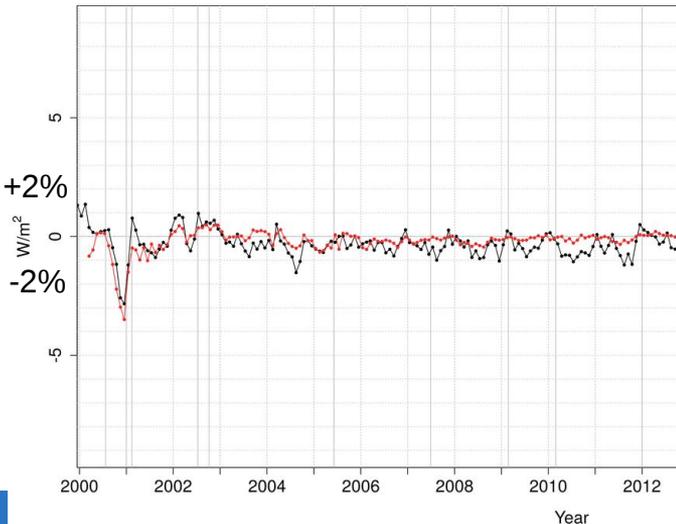
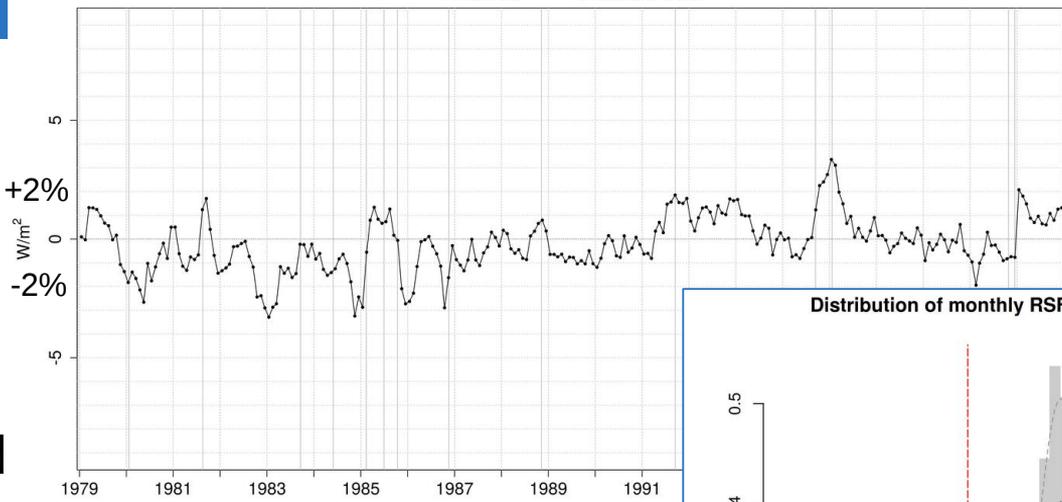
• **Global mean bias of Daily Mean RSF:**

• **Deseasonalized**



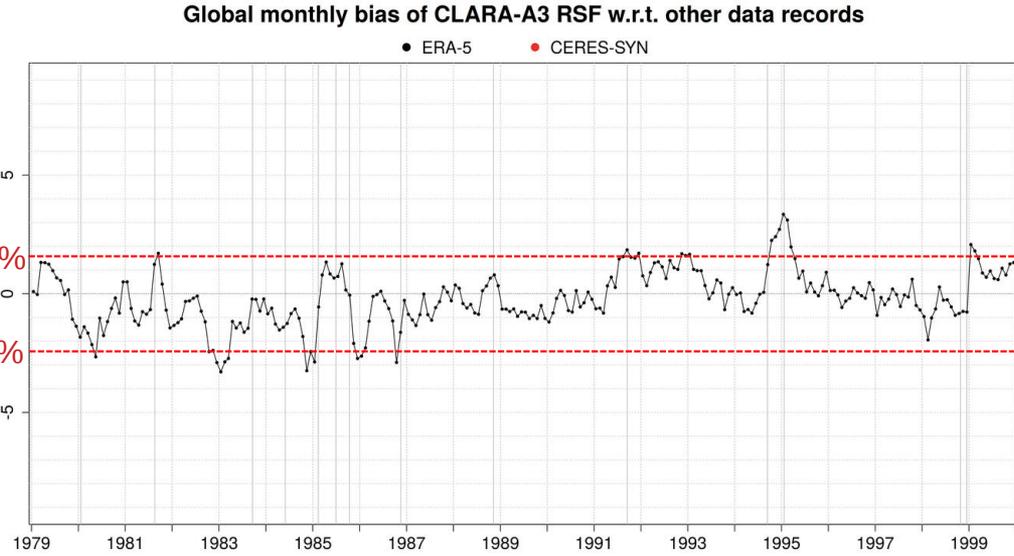
• **Global mean bias of Daily Mean RSF:**

• **Deseasonalized**



• **Global mean bias of Daily Mean RSF:**

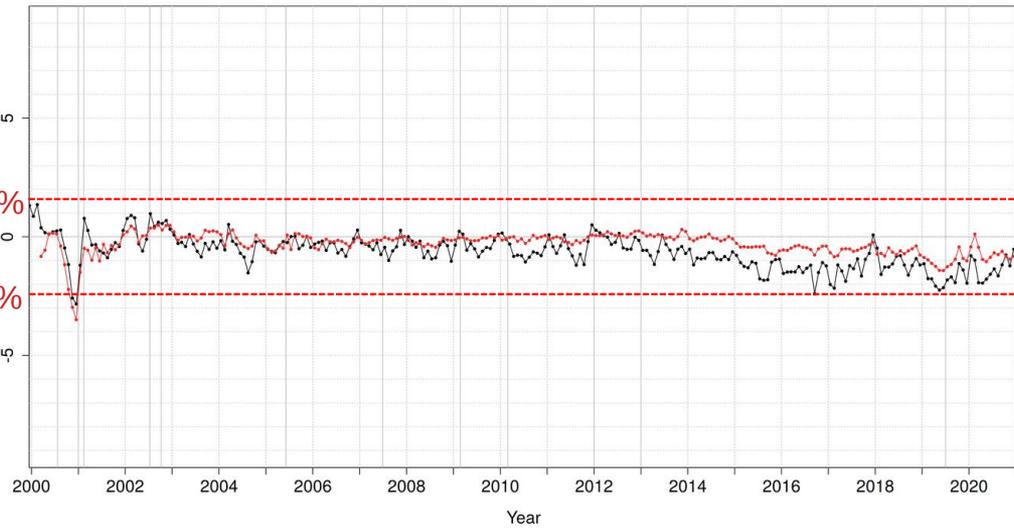
mean+2%
 mean-2%



93% of months are within mean +/- 2W/m² (about +/-2%)

• **Deseasonalized**

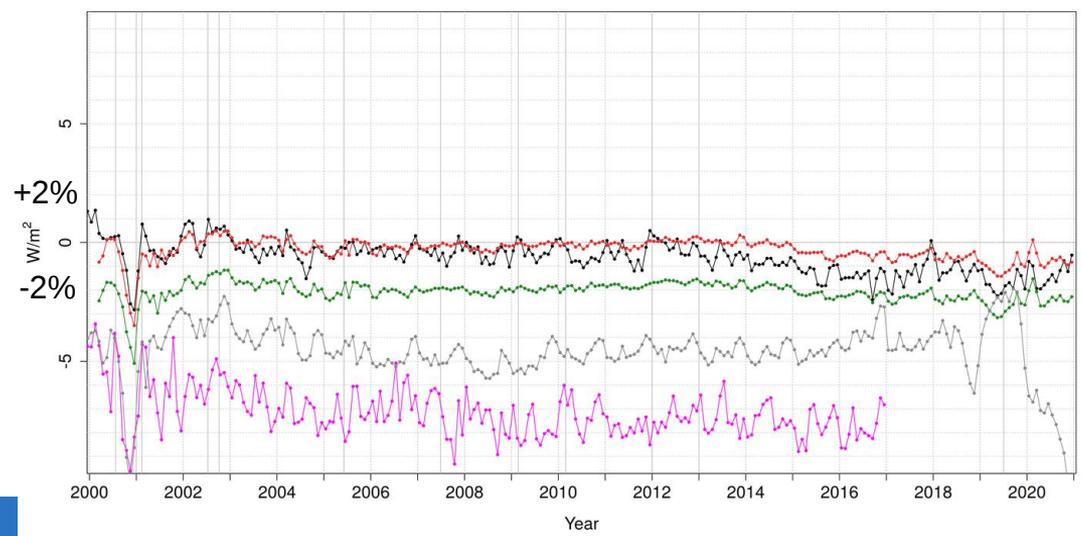
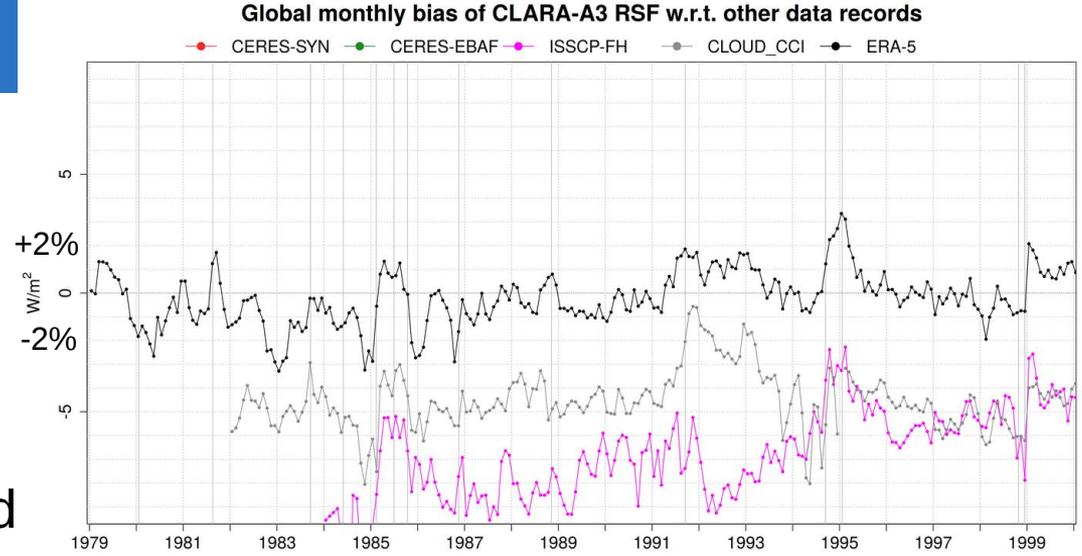
mean+2%
 mean-2%

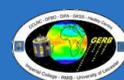


Trend of bias: -0.1547 W/m²/dec

- **Global mean bias of Daily Mean RSF:**

- **Deseasonalized**



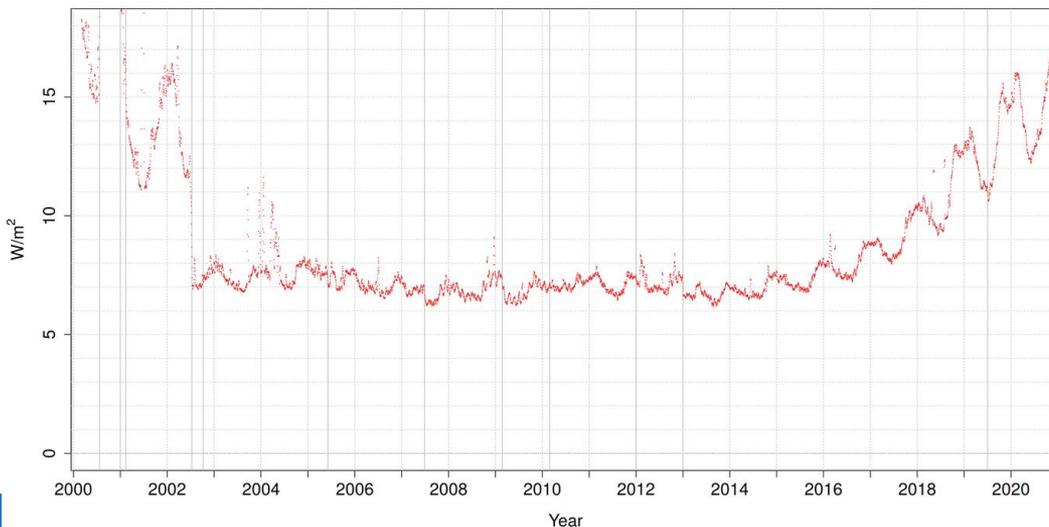
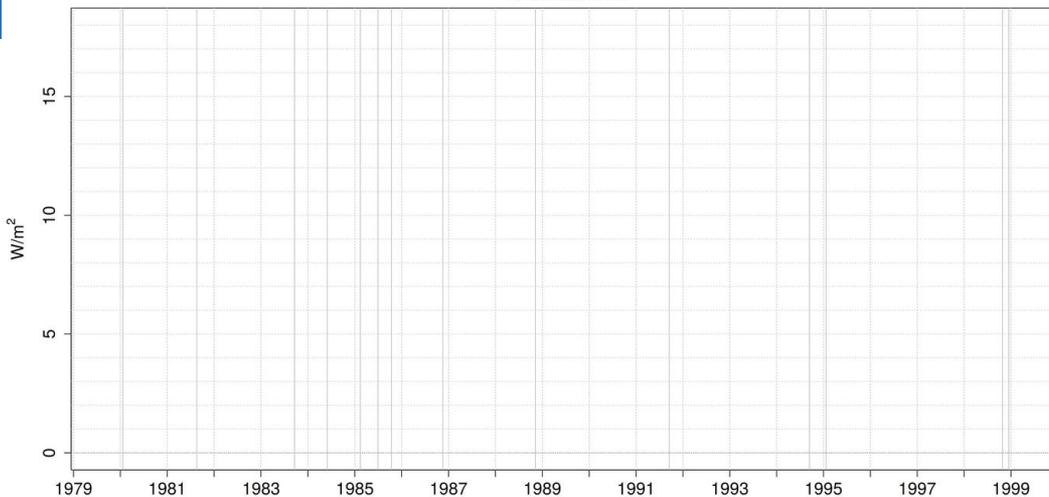


Global daily bc-RMSE between CLARA-A3 RSF and other data records

• CERES-SYN

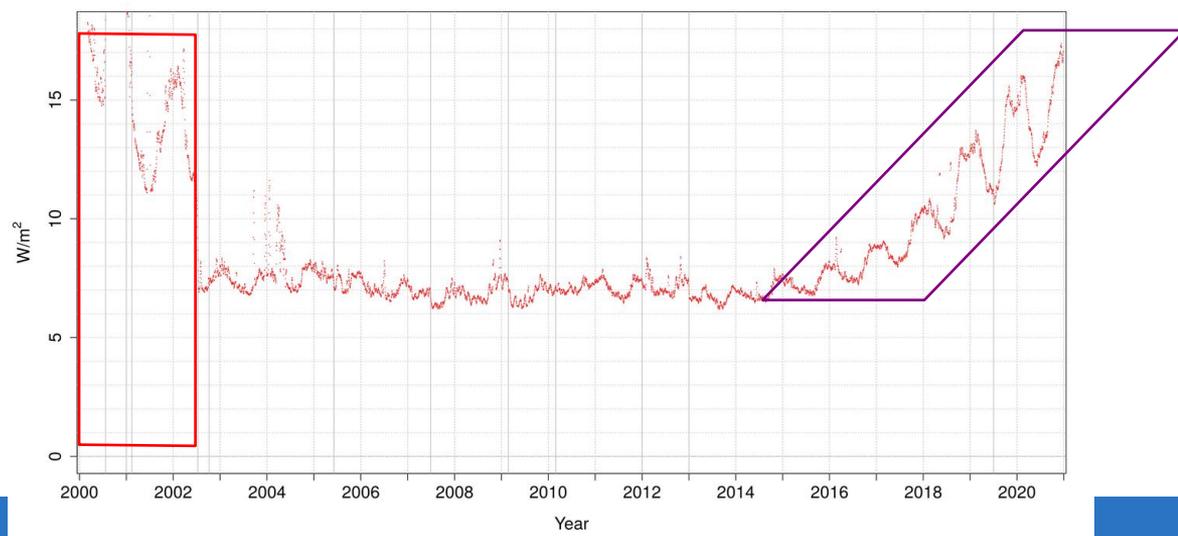
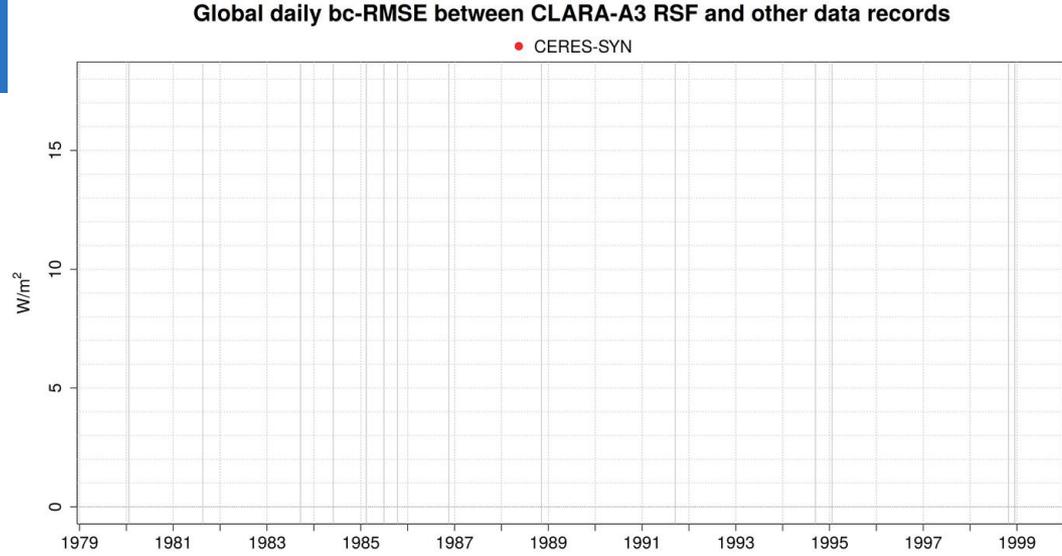
- Global RMSE
(bias-
corrected) of
Daily Mean
RSF:

- Weekly running average

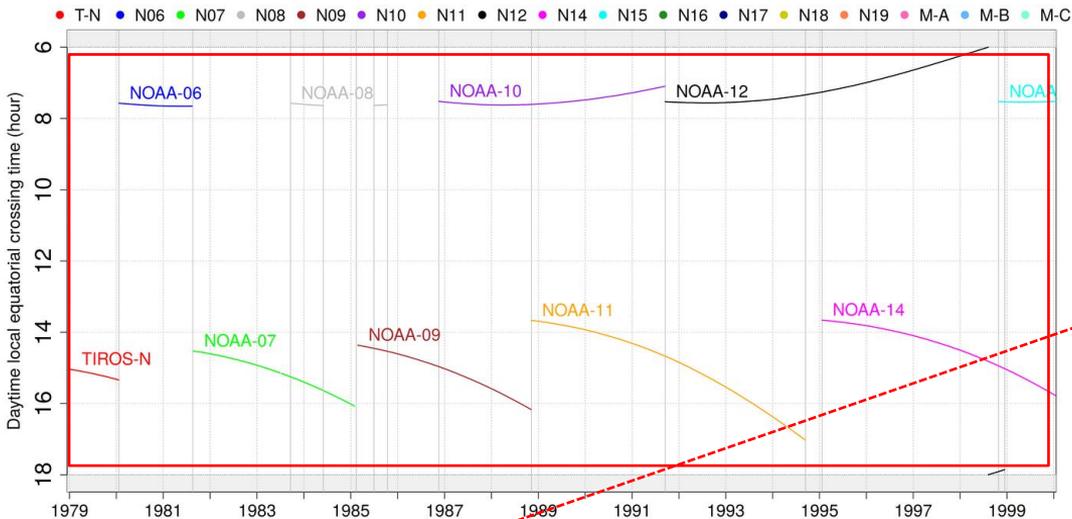


- **Global RMSE**
(bias-
corrected) of
Daily Mean
RSF:

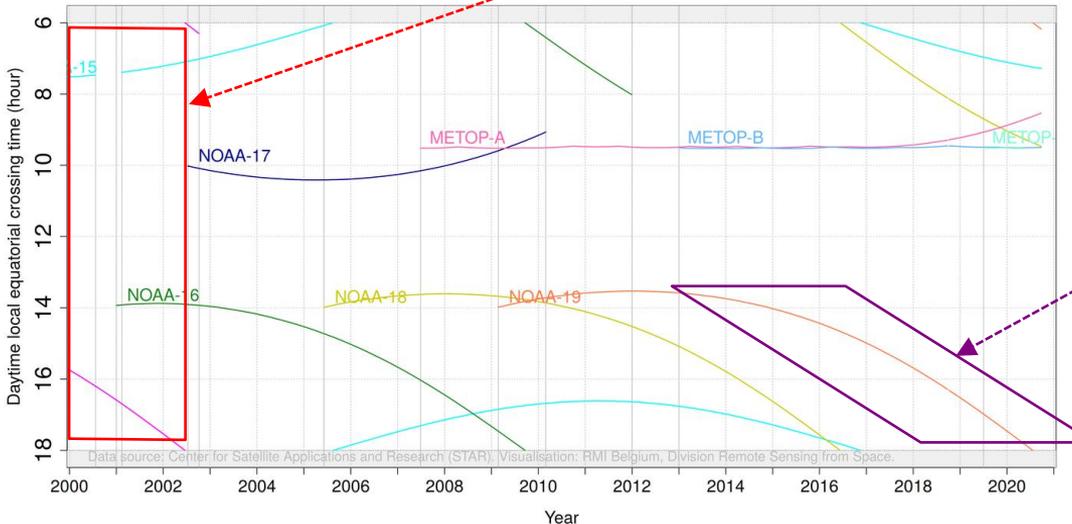
- Weekly running average



Daytime local equatorial crossing time of satellites used for CLARA-A3



No mid-morning orbit available (NOAA-17, MetOp)

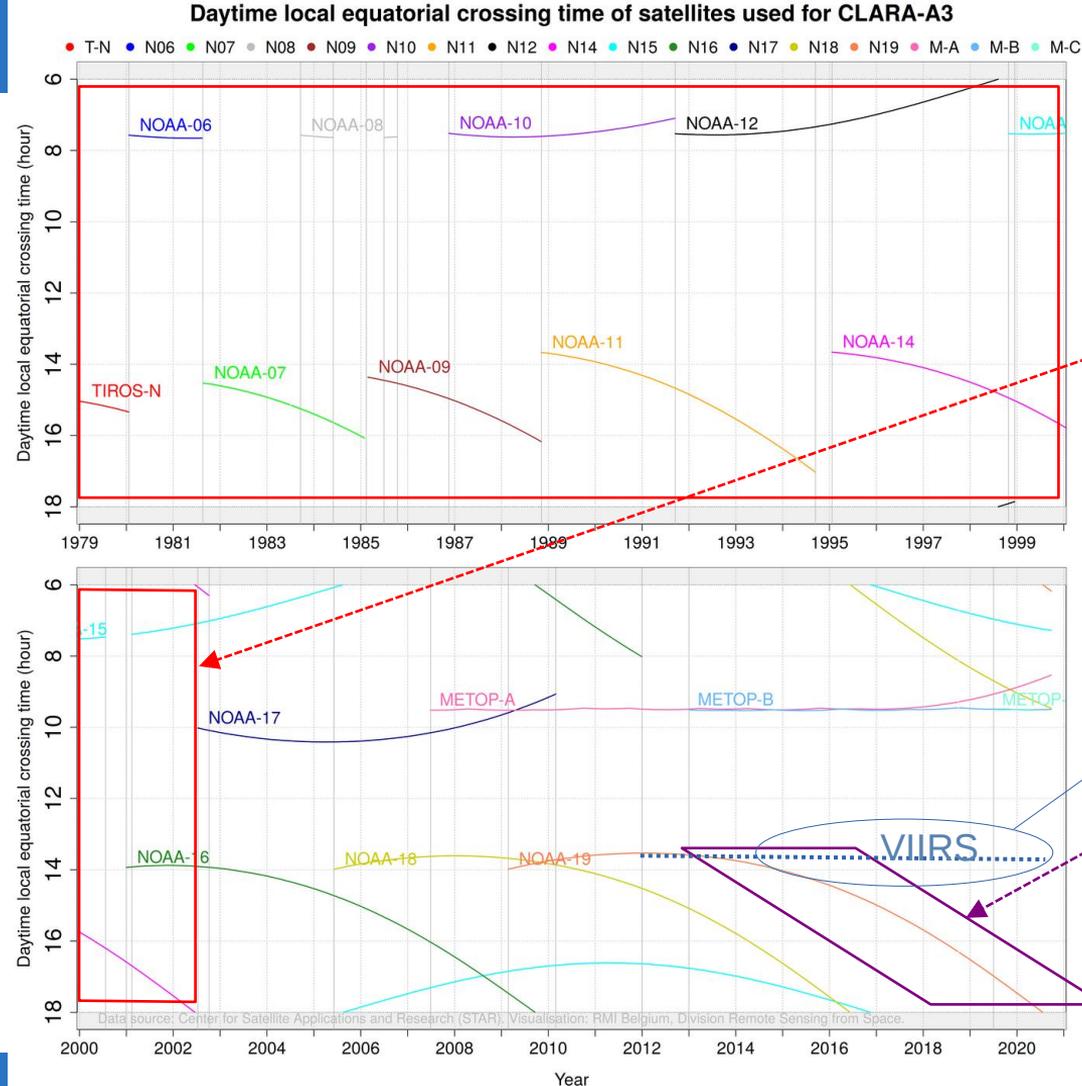


Orbital drift of afternoon satellite towards evening

• Orbital configuration of CLARA-A3:

Data source: Center for Satellite Applications and Research (STAR), Visualisation: RMI Belgium, Division Remote Sensing from Space.

Orbital configuration of CLARA-A3:



No mid-morning orbit available (NOAA-17, MetOp)

Next CLARA update includes VIIRS

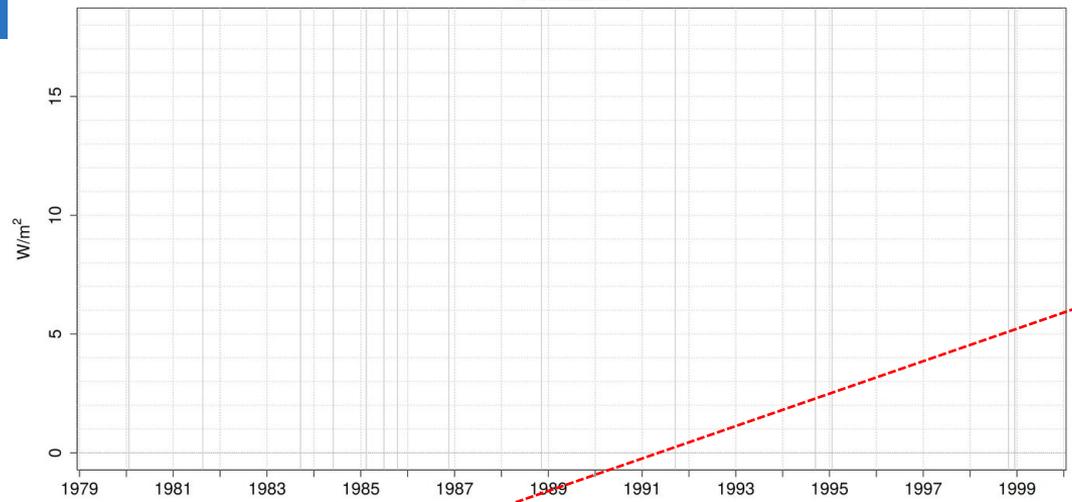
Orbital drift of afternoon satellite towards evening

Global daily bc-RMSE between CLARA-A3 RSF and other data records

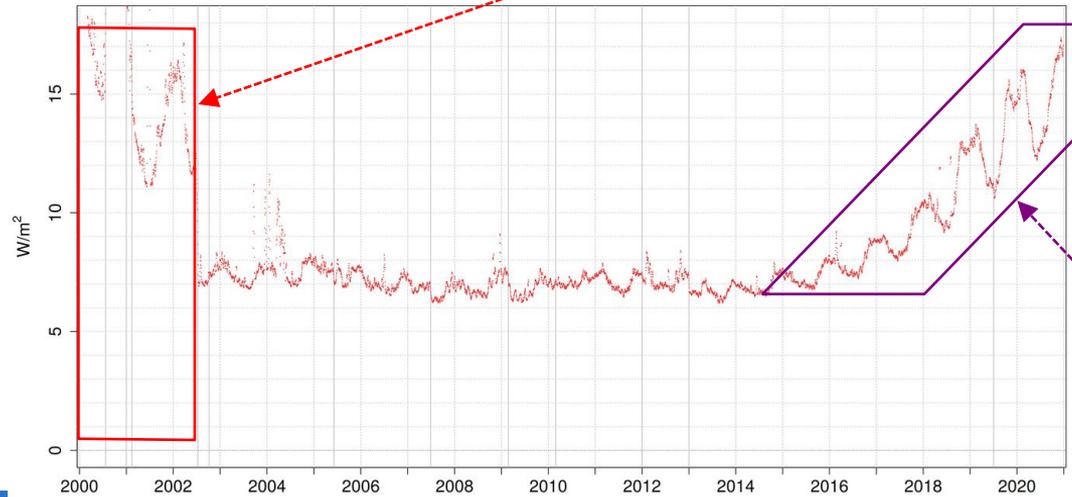
• CERES-SYN

• **Global RMSE**
(bias-
corrected) of
Daily Mean
RSF:

• Weekly running average

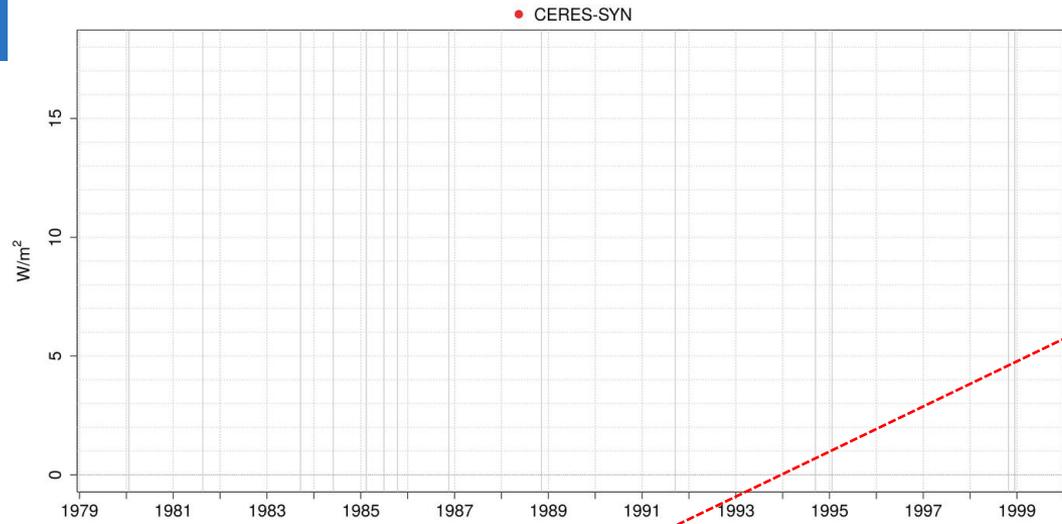


No mid-morning orbit available (NOAA-17, MetOp)



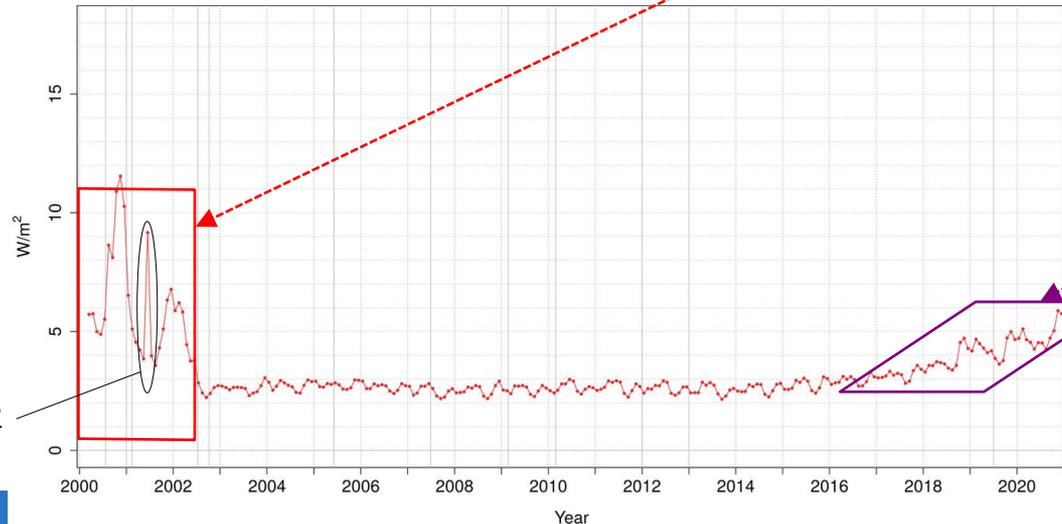
Orbital drift of afternoon satellite towards evening

• **Global RMSE**
(bias-
corrected) of
Monthly Mean
RSF:



**On monthly scale,
same effects but
less pronounced.**

**No mid-morning
orbit available
(NOAA-17, MetOp)**

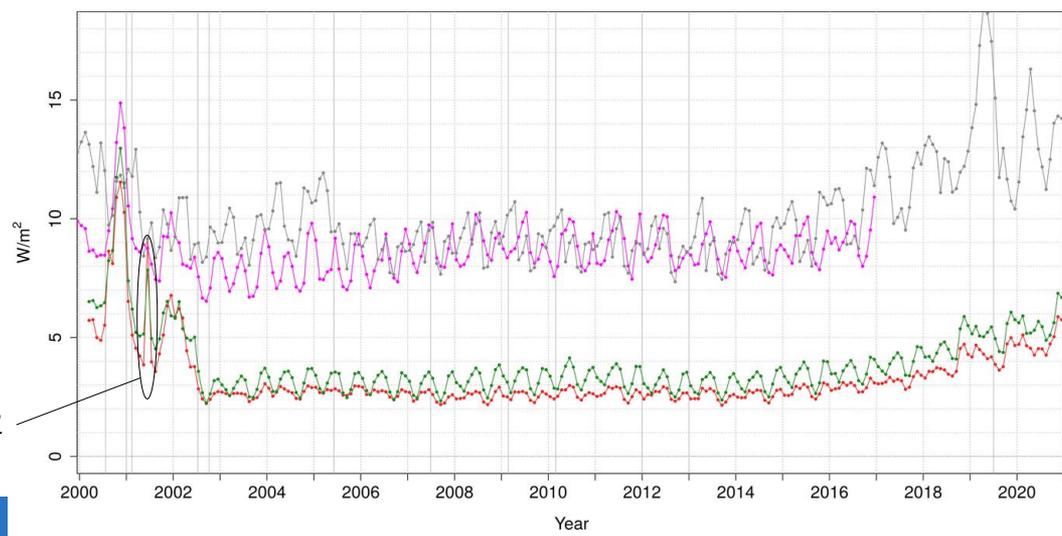
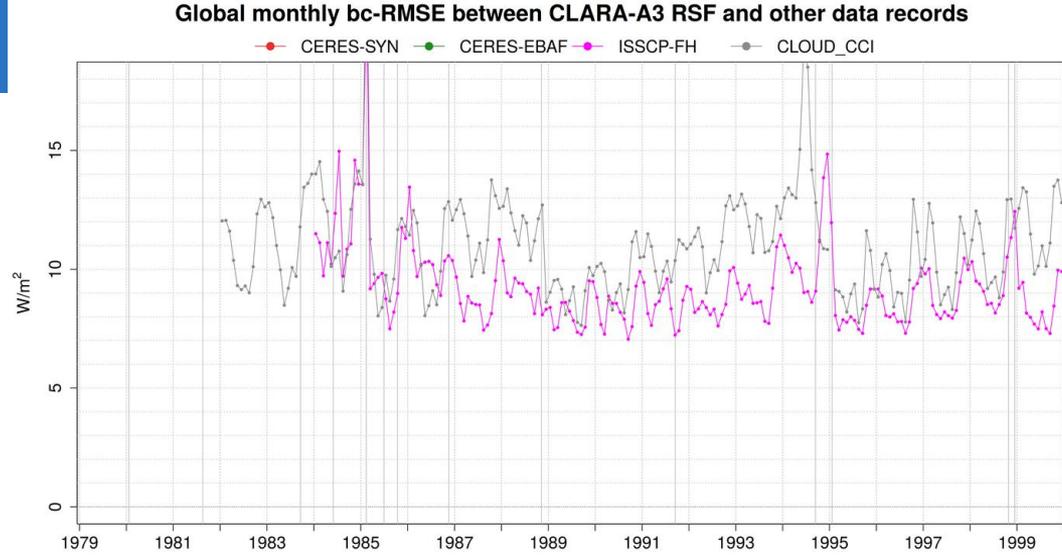


Strange artifacts in CERES Ed4.1

**Orbital drift of
afternoon satellite
towards evening**

- **Global RMSE**
(bias-
corrected) of
Daily Mean
RSF:

- Weekly running average



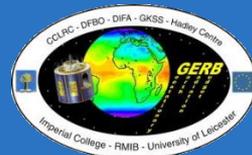
4. Future outlook

- Full data record of **CLARA-A3** has just been generated. After validation, release is foreseen around Q1 2023; an ICDR will also be developed
- Update **CLARA-A3.5** will include VIIRS instrument (S-NPP and NOAA-20) without any code changes (i.e. to be used as extension to CLARA-A3)
- Potential code updates will be done as part of **CLARA-A4** (within CMSAF), or as stand-alone data record (within RMIB), including:
 - Use of new CERES ADM's Ed4 (currently being implemented and tested at RMIB)
 - Use of new Narrowband-to-broadband regressions (based on reflectances with updated calibration coefficients, and updated scene types).

The Climate Monitoring SAF Outgoing Longwave Radiation from AVHRR
 by Nicolas Clerbaux, Tom Akkermans, Edward Baudrez, Almudena Velazquez Blazquez, William Moutier, Johan Moreels and Christine Aebi
 Remote Sens. 2020, 12(6), 929; https://doi.org/10.3390/rs12060929
 Received: 31 January 2020 / Revised: 3 March 2020 / Accepted: 10 March 2020 / Published: 13 March 2020

Retrieval of Daily Mean Top-of-Atmosphere Reflected Solar Flux Using the Advanced Very High Resolution Radiometer (AVHRR) Instruments
 by Tom Akkermans and Nicolas Clerbaux
 Remote Sens. 2021, 13(16), 3695; https://doi.org/10.3390/rs13163695
 Received: 23 August 2021 / Revised: 6 September 2021 / Accepted: 12 September 2021 / Published: 15 September 2021

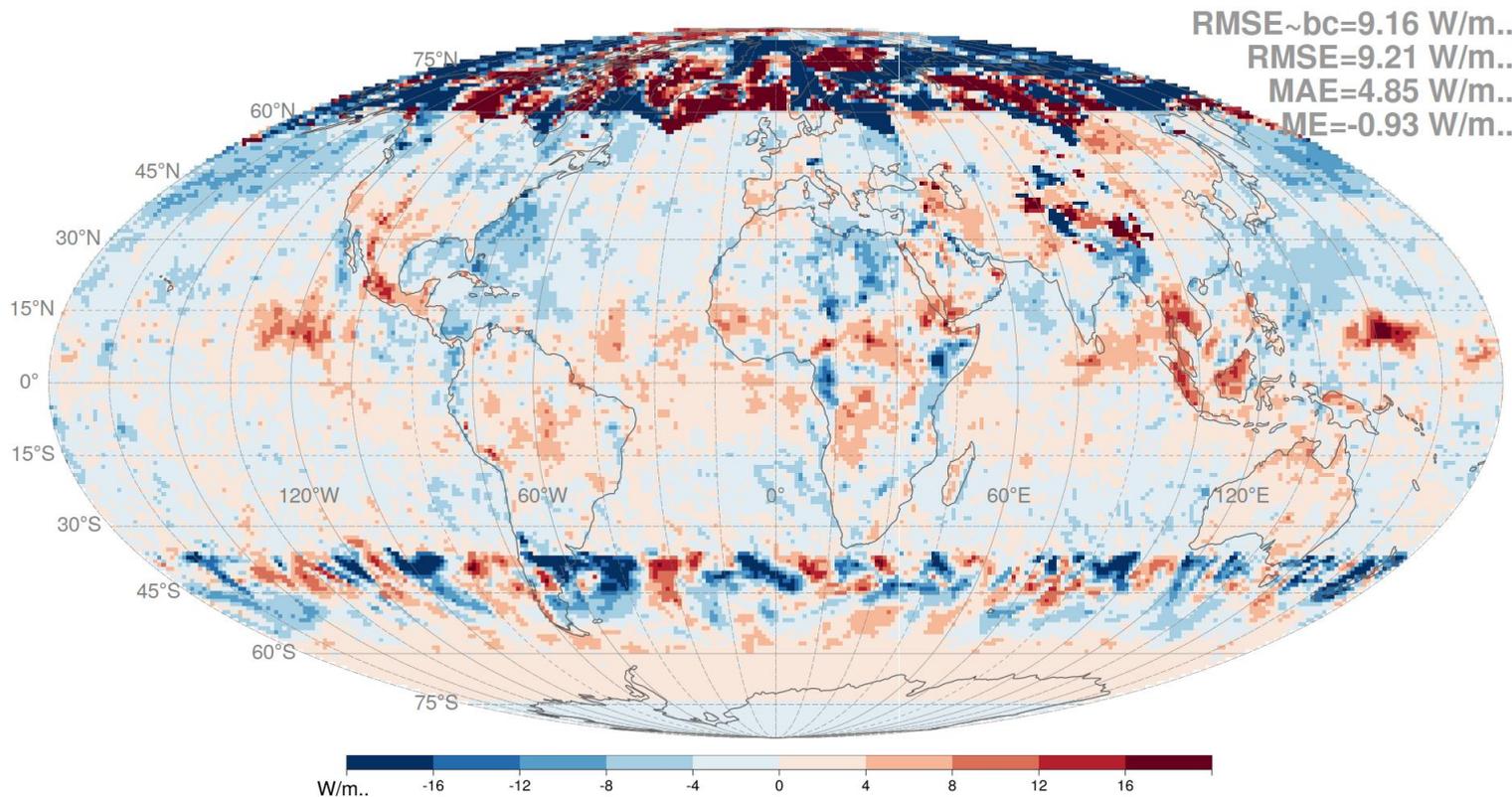
Abstract
 The records of the Advanced Very High Resolution Radiometer (AVHRR) have been used to create a long global climate data record of Reflected Solar Flux (RSF), by transforming these measurements into broadband flux at the top-of-atmosphere. This paper presents a methodology for obtaining daily mean RSF (Wm^{-2}) from AVHRR. First, the narrowband reflectances are converted to broadband reflectance using empirical regressions with the Clouds and the Earth's Radiant Energy System (CERES) observations. Second, the anisotropy using empirical regressions with the Clouds and the Earth's Radiant Energy System (CERES) observations is converted into a hemispherical albedo. Third, the instantaneous albedo is temporally interpolated by a flexible diurnal cycle model, capable of ingesting any number of observations at any time of day, making it suitable for any orbital geometry. A first step is the estimation of the instantaneous OLR from the AVHRR observations. Longwave Radiation (OLR), an important Earth radiation budget component, that is consistent with the CERES observations. A first step is the estimation of the instantaneous OLR from the AVHRR observations. Longwave Radiation (OLR), an important Earth radiation budget component, that is consistent with the CERES observations. A first step is the estimation of the instantaneous OLR from the AVHRR observations. Longwave Radiation (OLR), an important Earth radiation budget component, that is consistent with the CERES observations.



Thanks for your attention!

- Strange artefacts in CERES-SYN (RSF):

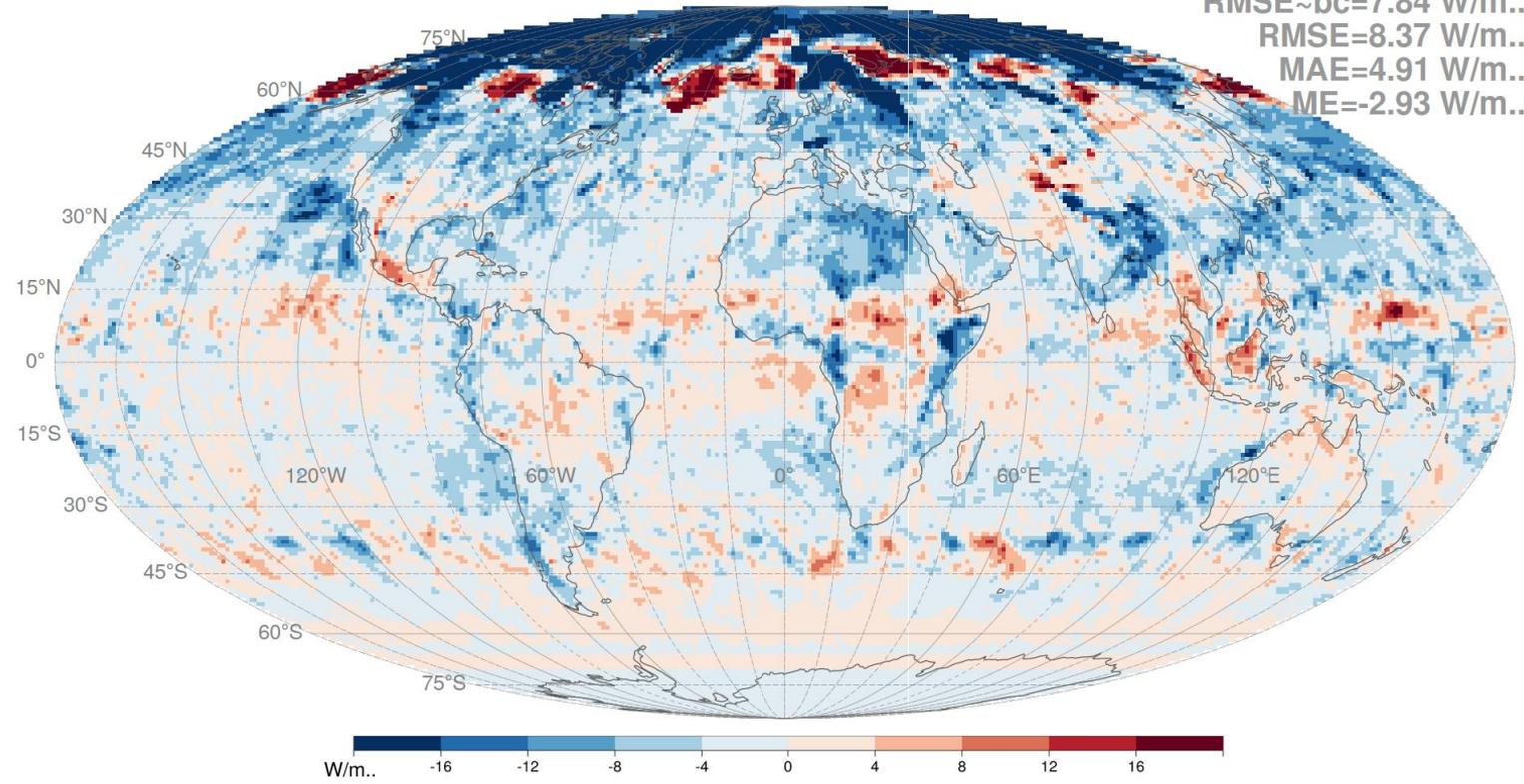
Bias of CLARA-A3 TOA RSF radiation w.r.t. CERES-SYNM-Ed4.1 (200106)



- Strange artefacts in CERES-EBAF (RSF):

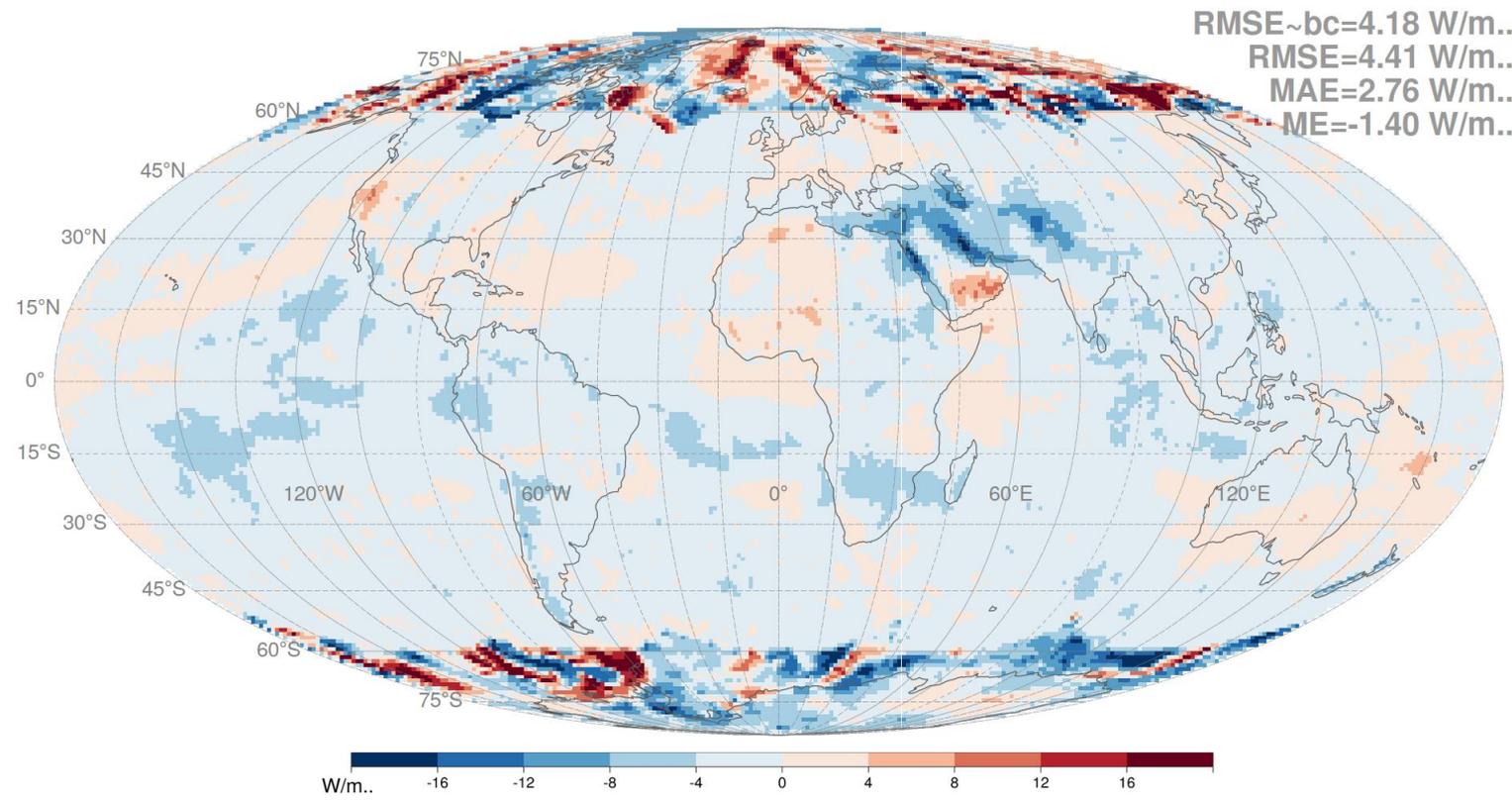
Bias of CLARA-A3 TOA RSF radiation w.r.t. CERES-EBAF-Ed4.1 (200106)

RMSE~bc=7.84 W/m..
RMSE=8.37 W/m..
MAE=4.91 W/m..
ME=-2.93 W/m..



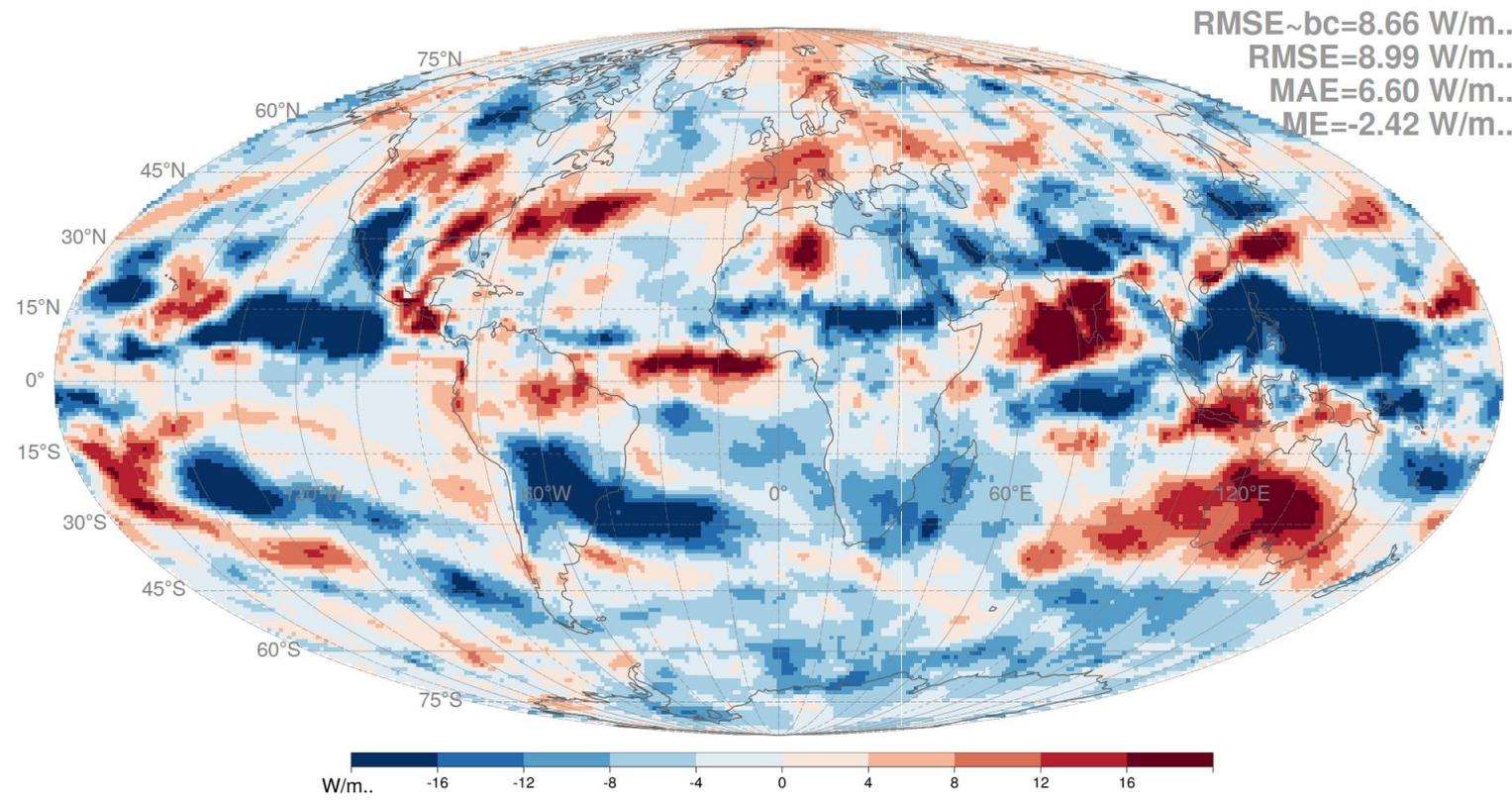
- Strange artefacts in CERES-SYN (OLR):

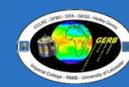
Bias of CLARA-A3 TOA OLR radiation w.r.t. CERES-SYNM-Ed4.1 (200106)



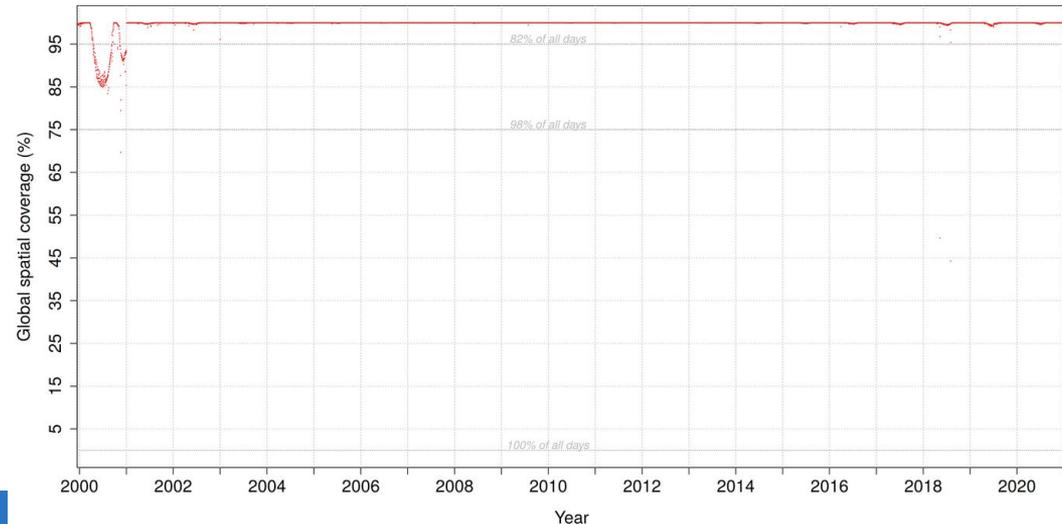
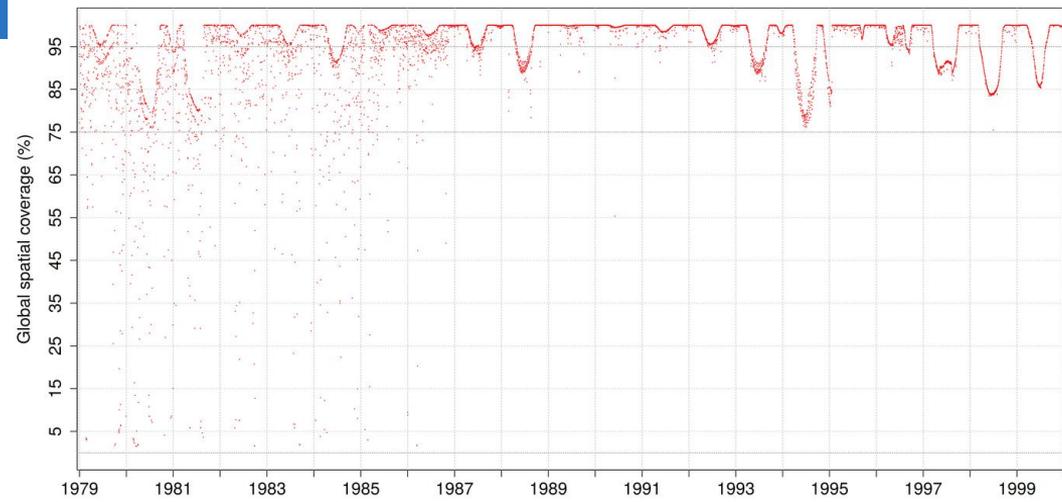
- Strange artefacts in CERES-SYN (OLR):

Bias of CLARA-A3 TOA OLR radiation w.r.t. CERES-EBAF-Ed4.1 (200106)

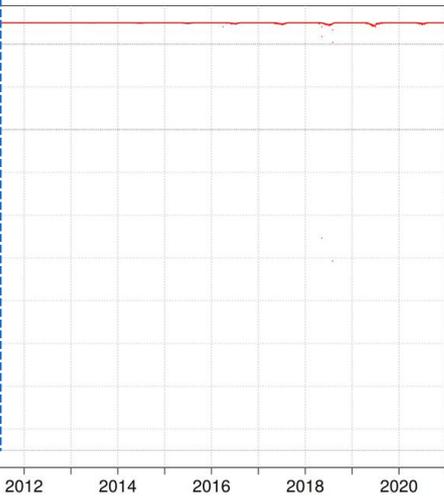
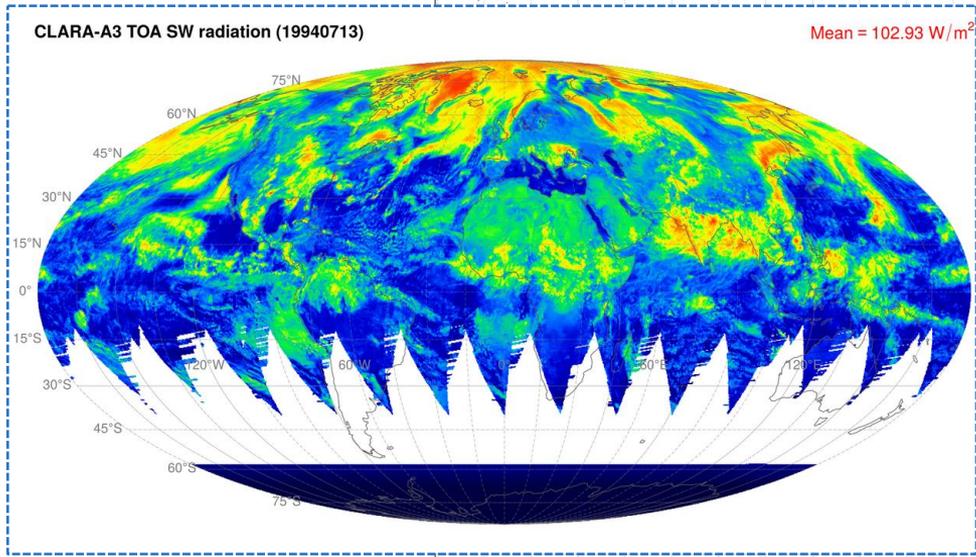
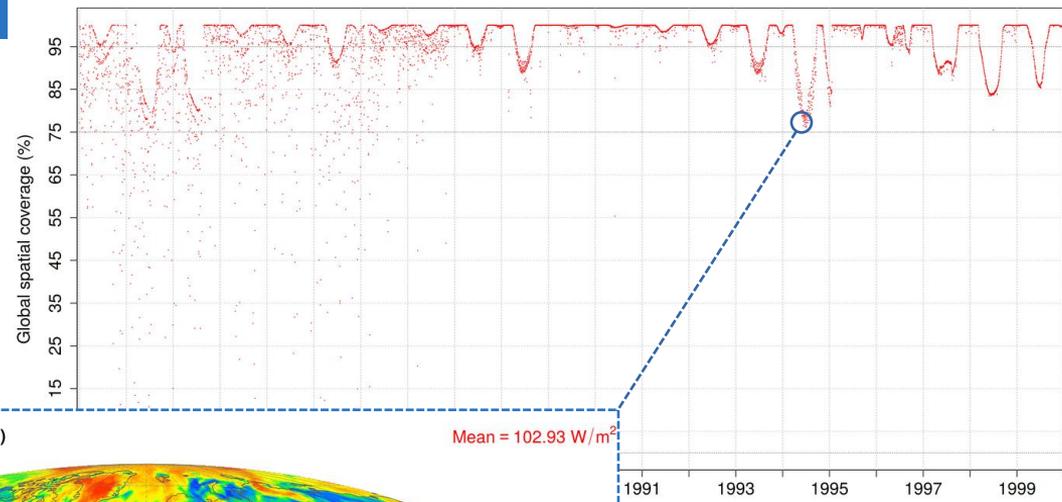




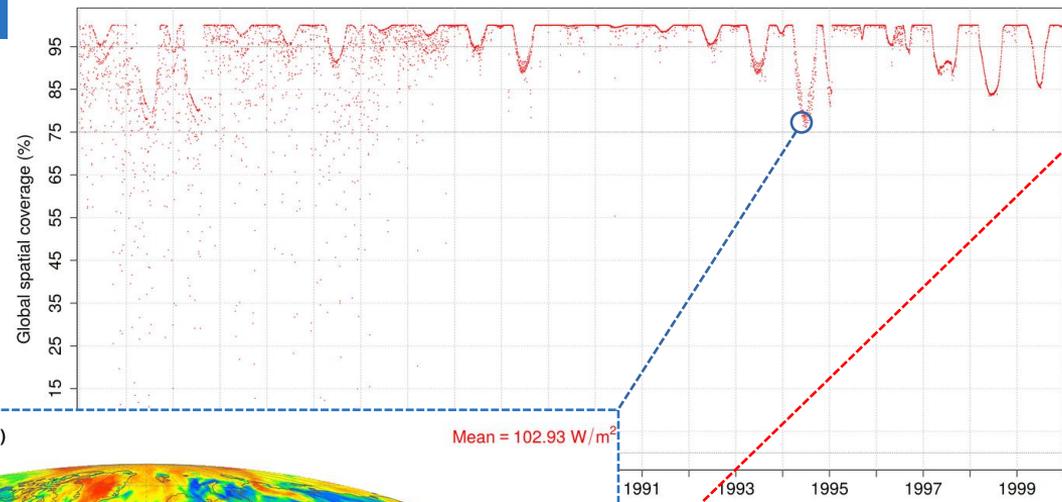
- **Global spatial coverage** of each RSF daily mean (%).



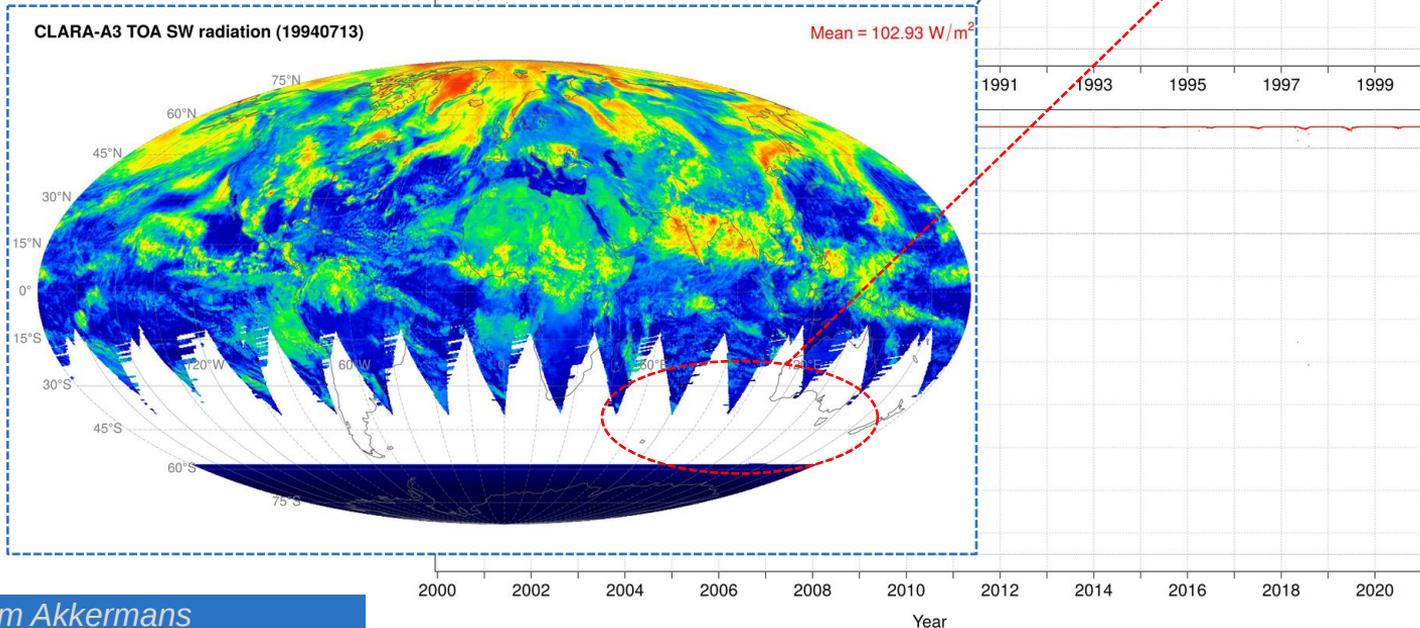
- **Global spatial coverage** of each RSF daily mean (%).



- **Global spatial coverage** of each RSF daily mean (%).



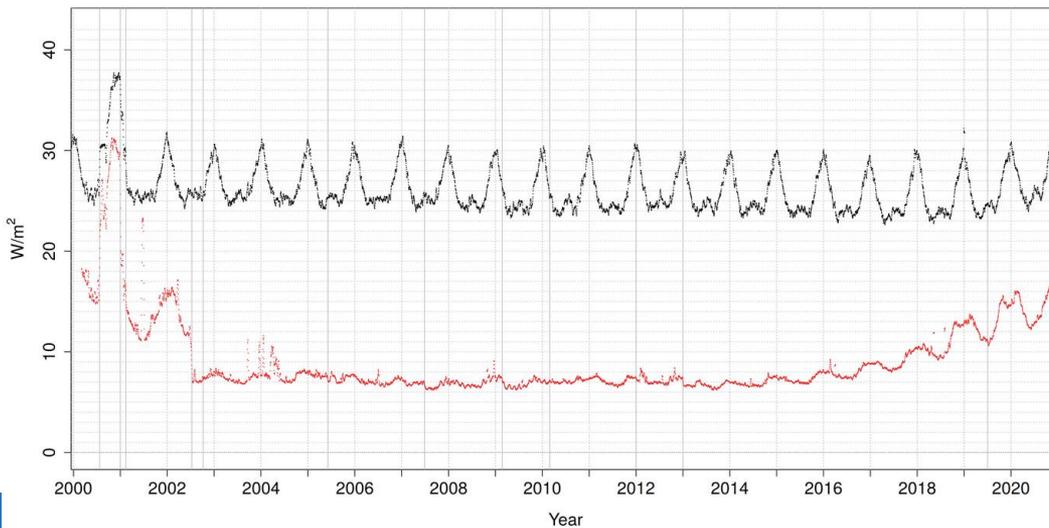
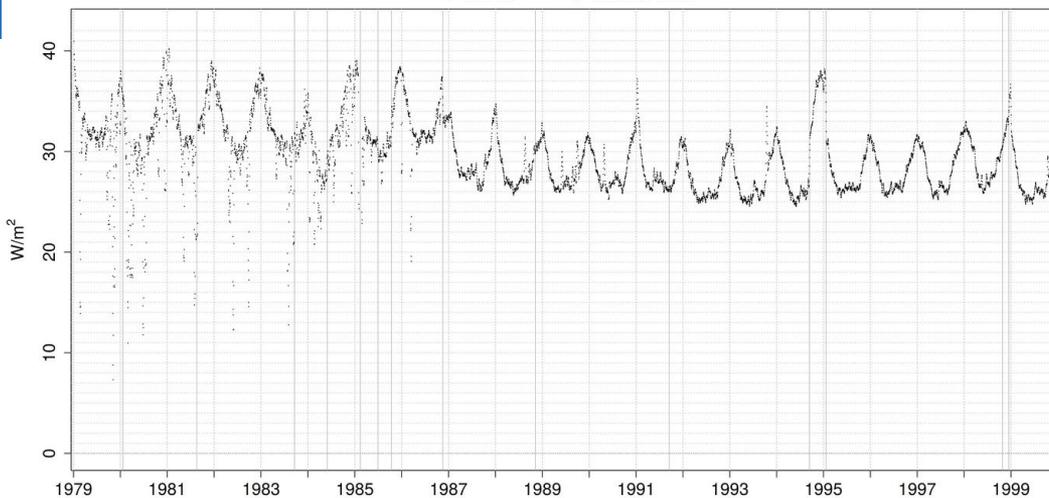
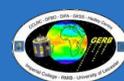
- Missing areas are filled with ERA5.
- If entire day is missing (i.e. 0% coverage), then no filling is done.





Global daily bc-RMSE between CLARA-A3 RSF and other data records

● ERA-5 ● CERES-SYN



- ERA5 annual mean OLR:

